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54 ☐ What can be more instructive than to have a venerated practitioner detail where he went wrong? **Hooper** does just that.

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8 ☐ **View from the Top**
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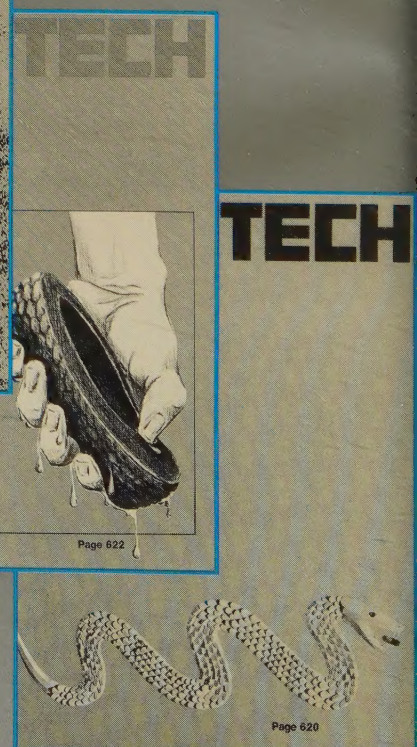
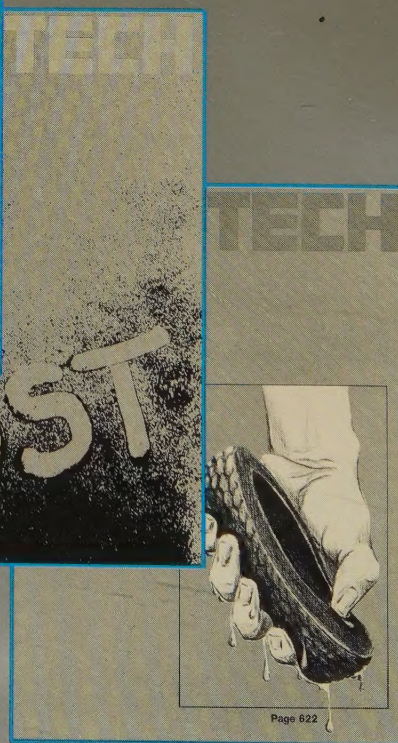
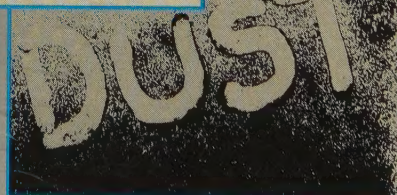
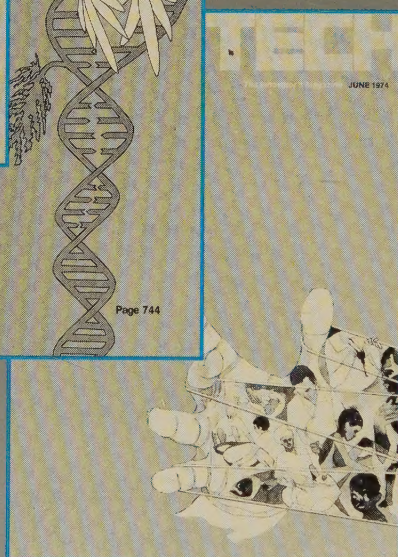
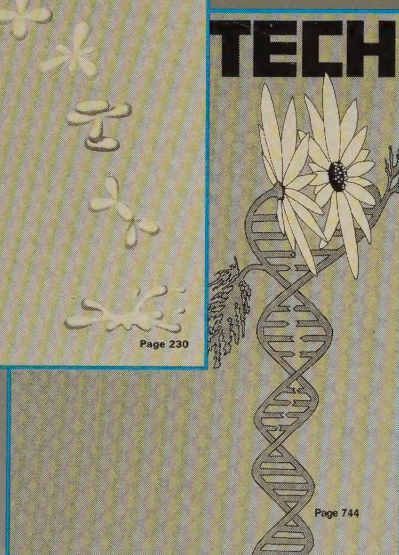
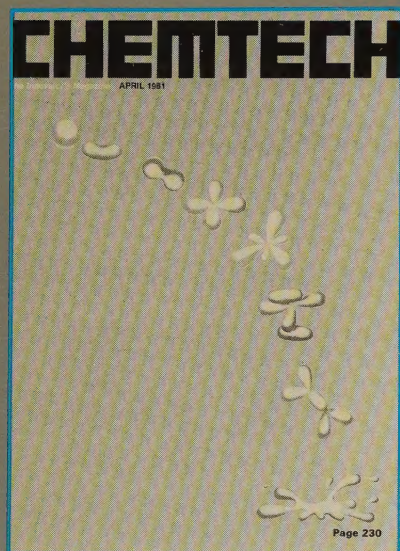
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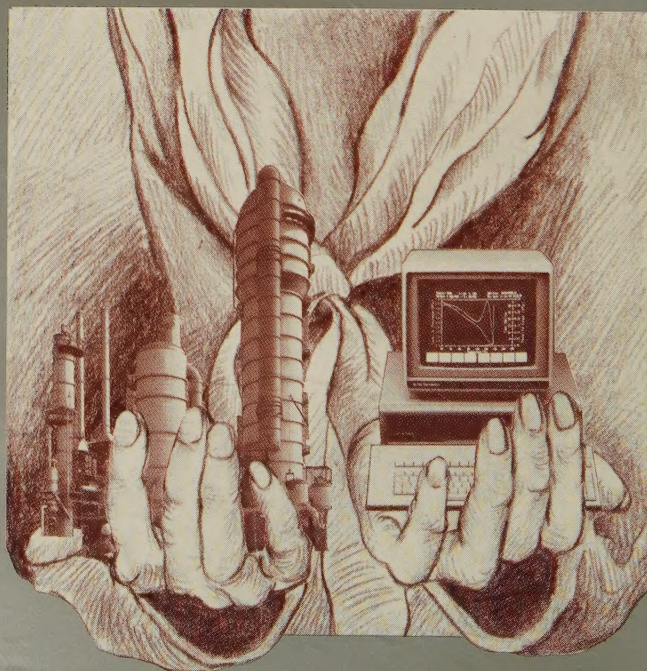
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- Alar PR** 264 ☐ How public pressure was incited against a benign growth regulator is revealed by **Fishbein**.
- Max Tishler: Pioneer** 268 ☐ One of the greats of chemistry died last year. **Kauffman** relates what made him great.
- The natives knew** 275 ☐ Why insects eat some plants and not others is a question with an intriguing chemical answer. **Berenbaum**'s thesis is that the Indians may have known it all along.
- The partially controlled economy Part 1** 280 ☐ If you're going to control something it's important to understand control theory and its limitations. That insight is provided by **Shinnar**, especially for those who have to deal with economics.

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- ☐ **IBC The Last Word**
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- Corporate eyes, ears, and mouths** 390 ☐ Big firms have changed the way they listen and respond both outside and in, says **The Economist**.
- The joys of excellence** 392 ☐ Everybody's talking about it. **Massingill** has some ideas on how to achieve it.
- Expert knowledge and the thinking process** 394 ☐ Start with a definition of competence, as **Glaser** does, and see where it gets you.
- The C word: A horror story** 398 ☐ "What became of the promised land?" **Wechsler** wonders.
- Translating technical 日本語** 401 ☐ Relatively new in the United States is the feeling of inadequacy that goes with not understanding the language of people who understand yours. **Bird** suggests ways to overcome that feeling.
- Quality improvement: A case study** 406 ☐ Few realize explicitly that a major benefit of ACS activity is the experience it gives in getting things done through others. **Borchardt** exemplifies.
- Mining chocolate chip cookies, and other educational adventures** 408 ☐ The SATIS program helps kids see science in action. **Licata** provides examples.
- Making a polymer pilot plant** 412 ☐ From concept to commissioning, **Calderone** and **Lawlor** tell it like it was.
- How to blend ionomers** 418 ☐ This practical guide to miscibility control, by **Natansohn**, **Murali**, and **Eisenberg**, opens vistas to polymer property enhancement.
- Graphite fluoride: A new material** 426 ☐ You just can't wet it, which is what makes it a good lubricant, mold release agent, and more. **Nakajima** and **Watanabe** describe the stuff and its preparation.
- The body's potassium channels** 432 ☐ Although this simple ion regulates so many vital functions, **Steinberg** and **Robertson** feel that new understanding will permit better therapies.
- Catalysis in direct coal liquefaction** 439 ☐ Sooner or later we're going to have to convert coal directly to liquid transportation fuels. **Derbyshire** suggests one way to do it sooner.
- Solving the cellulose enigma** 444 ☐ Finally there's a reasonable explanation of how two crystalline forms of cellulose interconvert without "melting." **Turbak** and **Sakthivel** provide it.

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386 **Write On**
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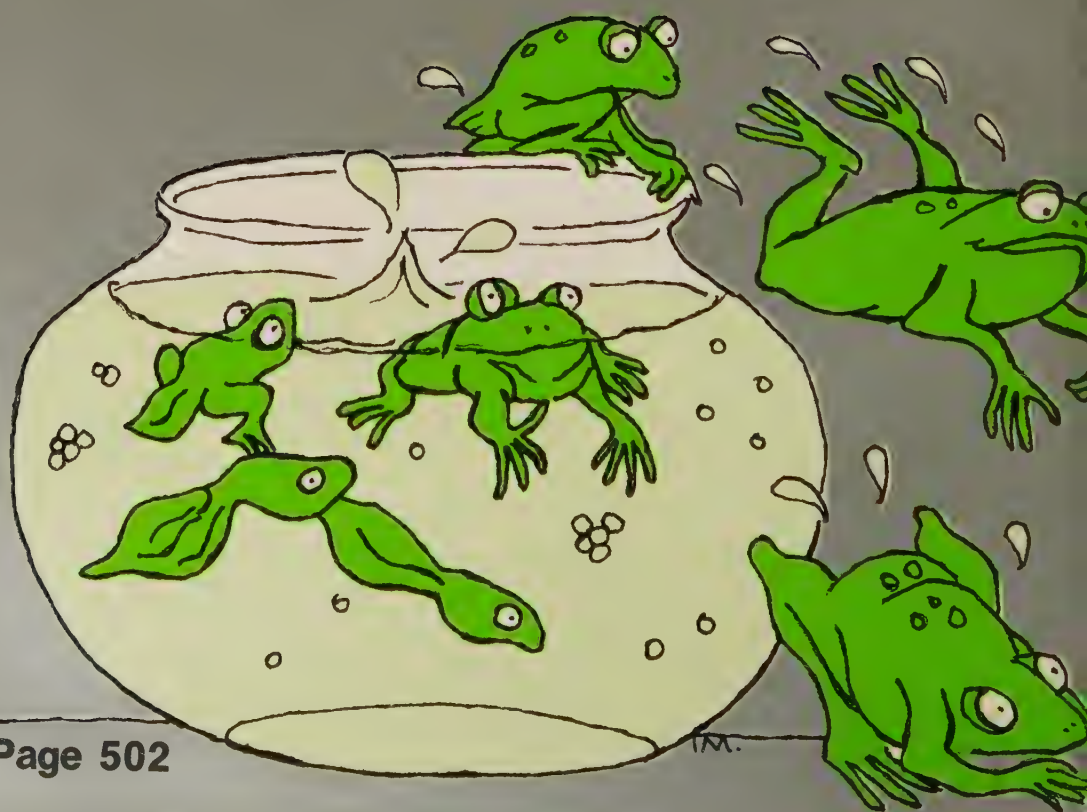
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Cover Photography: Norm Dresner

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Educating Prometheus

I should like to throw doubt on one assumption underlying the endless talk on specialization versus general culture—namely, the assumption that this pair of ideas really is antithetical. One rough and ready way to define general culture is to study the men who by common consent exhibit this virtue. And if we do this we find that most are specialists. Indeed many have had a vocational training (such as medicine or engineering).

If we look more closely at the writings of these admittedly cultured men, or listen to them as they talk, we discover that the quality of their minds does not depend on the diversity of their knowledge but upon its integration. It is not what they know or do not know that determines how cultured they are; it is the attitude they have toward knowledge. It appears, therefore, that the path to culture crosses through a man's specialization, rather than bypassing it.

Suppose a student decides to take up brewing: His way to acquire general culture is not by diluting his brewing courses with popular lectures on architecture, social history, and ethics, but by making brewing the core of his studies. The *sine qua non* for a man who desires to be cultured is a deep and enduring enthusiasm to do one thing excellently. So there must first of all be an assurance that the student genuinely wants to make beer. From this it is a natural step to the study of biology, microbiology, and chemistry—all subjects that can be studied not as techniques to be practiced but as ideas to be understood.

As his studies gain momentum the student will naturally become interested in the economics of marketing beer, in public houses, in their design, in architecture, in the history of beer drinking from the time of the early Egyptian inscriptions (and so in social history), or in the unhappy moral effects of drinking too much beer (and so in religion and ethics).

The territory of general culture needs to be liberated from occupation by the classical humanists. Let no one deny that some of the classical humanists themselves possess general culture and have made massive contributions to the cultural tradition of Europe. But the threads of culture change color, and it appears today as though technology will become the key to general culture. Technology—not science—because scientific systems are too self-contained; they exclude too many factors, including man, whereas the technologist has to make something that requires as its ingredients not only science but also an understanding of popular art and commerce, of psychology, something of morals and justice, and skill in the art of communication. A technologist who can weave his technology into the fabric of society can undoubtedly claim to have what the Conference of Rectors and Vice Chancellors calls general culture.



If these arguments are acceptable, the antithesis between specialization and general culture appears. It is the spirit of pursuit that matters. If universities ensure that science and technology are taught primarily as ideas to be understood rather than as techniques to be practiced (the education for practice can follow afterwards) there need be no more anxiety about a balance between specialization and general culture: the one would become the gateway to the other.

Acknowledgment

This timeless work was originally published in 1955 (*Research*, 1955, 8, 419). It was brought to our attention by Robert Essenhigh.



Sir Eric Ashby is a former Master, Clare College (Cambridge, U.K.). He has studied and taught botany from Australia to England to Chicago. He worked in Moscow, Nigeria, and Michigan, in addition to holding important university and advisory positions in Britain. He was honored for his work with a Life Peerage granted in 1973.

On the first floor of the Deutsches Museum in Munich there is a laboratory table that contains an apparatus for the neutron activation of uranium. The table bears the label "worktable of Otto Hahn." In August the museum agreed to give Lise Meitner (CHEMTECH, January 1989, p. 17) the equal credit she should have for the work, for, in truth, she designed the apparatus on the table and pointed out the importance of the results to Hahn, who won the 1944 Nobel Prize for the discovery (*Nature* **1989**, 340, 497).



The design of the blood-pressure-lowering drug captopril was based on the hypothetical binding site of the angiotensin-converting enzyme (Cushman, D.; Ondetti, M. CHEMTECH, October 1982, p. 620). The enzyme, which causes an increase in blood pressure, is a polypeptide that was originally found in the kidney. But components of the renin-angiotensin system (RAS) also have been found in various tissues, including blood vessels, heart, lung, intestine, and brain. Recent advances have shown

that the RAS also affects reproduction and the body's immunity. For an overview see the article by M. Ehlers and J. Riordan in *Biochemistry* (**1989**, 28[13], p. 5311).



The question of how Egyptian pyramids were constructed has fascinated historians for centuries (see Noether, D., CHEMTECH, November 1989,

p. 658). Although the tombs told much about the lives of nobility, new interest concerns the lives of working folks. Excavations have uncovered remains of bakeries and breweries, and archaeologists are now looking at the workers' living quarters (Wilford, J. N. *New York Times*, July 11, 1989, p. C1). In the sediment beneath mud wall remnants, researchers have found pieces of flint, copper, and glazed tile, indicating the presence of a sculptor's workshop. Other clues have been ashes, fish bones, clay pots, small tombs, and a stone effigy of a round-faced man. The newly discovered barracks are southeast of the Giza pyramids.

OOPS!

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A transparent fluorocarbon with better light transmission (95%) than poly(methylmethacrylate), polycarbonate, or even plate glass has been developed by Asahi Glass Company. The company has started construction of a pilot plant for the new resin (*Plast. Ind. News*, April 1989, p. 51). (HWY)

A revival of interest in Ziegler-Natta catalysis has focused on the use of aluminoxanes, formed from aluminum alkyls and water. Although excess water turns aluminum alkyls to alumina (with vigorous heat evolution!), aluminoxanes are formed when water is present in limited amounts. When used as part of a Ziegler-Natta catalyst in combination with a transition-metal compound (such as titanium tetrachloride), the aluminoxanes can produce a syndiotactic polymer, instead of the isotactic polymer made with conventional catalysts. The **different structure can influence polymer properties**. The syndiotactic form of polystyrene, for example, has a melting point 40 degrees higher than that of its isotactic analogue, as reported by N. Ishihara,

M. Kuramoto, and M. Uoi (*Macromolecules* 1988, 21, 3356). These same workers report the preparation of substituted syndiotactic polystyrenes. A. Zambelli and co-workers (*Macromolecules* 1989, 22, 104) also report the production of syndiotactic copolymers. (HWY)

Photodecomposition of water can be achieved by using semiconductor particles that transfer electrons and holes. But the observed quantum yields are small, the reproducibility is poor, and often only hydrogen is liberated while oxygen remains bound to the catalyst. The use of silver phosphate has surmounted these difficulties and has shown an unusual behavior in **photogenerating both hydrogen and oxygen** simultaneously from water without electron- or hole-transfer catalyst (Tennakone, K.; Jayatisso, A. H.; Wijeratne, W. *Chem. Commun.* (1988, 496). A likely process is outlined by the authors, who explain why silver phosphate can liberate molecular oxygen without the help of electron-transfer catalyst. (PLS)



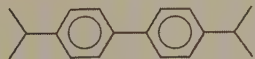
William J. Bailey 1921-1989

This issue of CHEMTECH, fittingly the first of volume 20, is dedicated to Research Professor William J. Bailey of the University of Maryland, College Park. Before he was President of the American Chemical Society or Chairman of its Board, Bill served on CHEMTECH's Advisory Panel. He died suddenly on December 17 in Honolulu during the opening reception of The International Chemical Congress of the Pacific Basin Societies, among colleagues and friends from around the globe.

Bill was appointed to our Advisory Panel by the ACS Polymer Division in 1973 and served for 10 years. He brought us a unique combination of scientific acumen, educational insight, political sensitivity, and high-humored creativity. He also brought your Editor outspoken support during CHEMTECH's formative years and warm friendship in later ones. Though he leaves a uniquely significant legacy of pioneering polymer science and productive students, his infectious smile and helping hand are already sorely missed.

Bill's family comprises Mary, his wife and companion of 40 years, who was with him here in Hawaii, their daughters Caroline Jane and Barbara Ann, son John Robert, and brother Robert. They have established the William J. Bailey Scholarship in the Department of Chemistry at the University of Maryland, College Park, College Park, MD 20742, to which remembrances may be sent.

Shape-selective reactions on zeolites are old news, but relatively little work has been done on shape-selective alkylation of polynuclear aromatics, such as naphthalene or biphenyl. This is surprising because disubstituted naphthalene and biphenyl are important building blocks for liquid crystal polymers. However, G. S. Lee and co-workers (*Catal. Lett.* 1989, 2, 234) now report a remarkably high yield of 4,4'-diisopropylbiphenyl



by **direct alkylation of biphenyl** with propylene over dealuminated mordenite. The key to high yield (72 %) of the para-substituted biphenyl seems to be the dealumination, which not only removes acid sites responsible for coking but also modifies the pore structure of the zeolite. (HWY)

One of those cures in search of a disease is sure to find a lot of diseases to attack. It's called **Un-Plot-It**. It attaches to an XY plotter and enables the darn thing to work in reverse. That is, you put any kind of graphic under its nose and it traces that graphic, digitizes it, and feeds it to your computer. Once there, you can do lots of things with it—expand the scale this way or that way, subtract one spectrum from another using any of the programs that enable you to manipulate data, and get structural formulas into your reports. It also fits curves to points and even reproduces photographs reasonably well. The whole thing—software and hardware (except the XY plotter)—is \$300 (801-377-6978). (BJL)

To the numerous reducing agents available in organic chemistry, three new ones have been added. They sound exotic, but A. Furstner and H. Weidmann (*J. Org. Chem.* 1989, 54, 2307) show they are highly selective and useful in **dealing with multifunctional molecules**. Potassium-graphite laminate (referred to as C8K) is prepared by heating potassium metal with graphite, under argon, at 150 °C. The bronze-colored material is used suspended in anhydrous THF. Zinc/silver-graphite and magnesium-graphite are prepared by reacting the appropriate anhydrous metal chloride with the potassium-graphite laminate.

What do they do? The potassium-graphite causes only dehydrohalogenation, the magnesium-graphite effects Wurtz reaction-type coupling of halides to give dimers. The zinc/silver-graphite reagent, on the contrary, gives dealkoxyhalogenations. (BST)

If you have had difficulties getting computer software fixed, take heart—the problem may not be on your end. (Small consolation, I know.) M. Ridgway writes in *Datamation* (1988, 34[25], 77) that computer science **curricula are not graduating individuals qualified** to carry out the duties that future employers will expect of them. Ridgway's main complaints are that programmers are not trained in maintenance programming, nor can they communicate effectively. Seems like this last failing is common to many curricula. (IBAP)

Japan New Materials Report provides insight into new materials in **general and Japanese accomplishments** in particular; below is a recent table of contents. Sample copies and subscription information can be obtained by writing to *Japan New Materials Report*, P.O. Box 4129, Bellevue, WA 48009-4129.

JAPAN NEW MATERIALS REPORT

Volume IV, Number 3

May-June 1989

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Functional groups on polymers can affect polymer properties and afford convenient sites for attaching still other groups to the polymer chain. So it was interesting to read the paper by S. Iwatsuki, et al. (*Macromolecules* 1989, 22, 38) on the preparation and polymerization of **dicyanostyrene and tricyanostyrene**. The preparation of the monomers was done by a multistep synthesis with 40 % overall yields for the dicyanostyrene and 0.15 % for the tricyanostyrene. Science so far, not technology. (HWY)

A short but lucid introduction to the use of zeolites for shape-selective catalysis is given by J. Dwyer in *Nature* (May 18, 1989, 339, 174). The phenomenon is based on the spatial restrictions at the active sites located in the zeolite pores. The restrictions affect not only the reactant and product molecules but also, in some cases, the reaction intermediates. The concepts are **well-illustrated by applications** to alcohol dehydration, hydrocarbon cracking, aromatic alkylation, methanol conversion to gasoline, and the aromatization of alkanes—all in less than two pages! (AJC)

Hydrocyclones, elutriators, centrifuges, cone and spiral classifiers, sieves, and filtration—all are used in commercial processes for particle separation and classification. Differences in gravitational settling rate

also have been used because they're simple, low shear, and cheap. But (isn't there always a BUT?) gravitational settling can also be slow. R. H. Davis, X. Zhang, and J. P. Agarwala (*Ind. Eng. Chem. Res.* 1989, 28[6], 785) examined **gravitational particle separators** with inclined channels for decreasing separation times. The theoretical method for prediction of particle separation agreed well with results from actual separations of polystyrene bead suspensions. (CMH)

Whether this reaction is $A + B \rightarrow C$ or $A + A \rightarrow B$ matters not. Nor should it concern you if the reaction is auto-oscillating with creation and destruction. All you need do is read the excellent review of second-order reactions in condensed media by V. Kuzovkov and E. Kotomin (*Rep. Prog. Phys.* 51[12], 1479). They state that the purpose for their study was to tighten up the **analysis of the simplest bimolecular reactions**. As they quote from Einstein, "Everything should be done as simply as possible but not simpler." In that same journal issue you will find a review of X-ray microscopy by A. G. Michette that will have you speaking and walking X-ray even if you've had only a passing interest in this technique. (MGT)

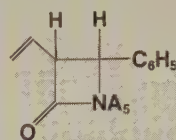
NMR spectroscopy of interesting solids is treated in 12 papers in the November 1988 issue of *J. Chem. Soc. Farad. I*. **Subjects include clathrates**, Pt-Rh clusters, zeolites, biological membranes, and crystalline organic compounds. (KFS)

Here's a surprise for those interested in the oxidation of hydrocarbons, for example, lubricating oils. B. H. Clampitt of Pennzoil reported at the 196th ACS National Meeting his findings on the oxidation of pure hydrocarbons in the lube oil range by using differential scanning calorimetry. With aliphatics he found just about what you'd expect: Straight-chain paraffins are more stable than branched paraffins, which are more stable than olefins. But when it came to aromatics there were surprises. Putting a phenyl group on a paraffin chain had little discernible effect on the observed induction period. On the other hand, introducing a naphthyl or anthryl group gave about what you'd expect: a **hot hydrogen leading to a short induction period**. The authors had no clear explanation for the observation but noted that "hydrogenation removes all of the unsaturates and aromatic compounds . . . overall this improves oxidative stability. It is unfortunate that we do not have techniques to selectively hydrogenate the unsaturated and alkyl polyaromatic compounds in base stock and leave the alkyl monoaromatic compounds. As things now stand the monoaromatics go to naphthenes which exhibit about half the stability of their precursors." (BJL)

The Manhattan Project provided the stimulus that led to the remarkable success of organofluorine chemistry, most notably high stability fluorinated polymers and fluorine-substituted agrochemicals and pharmaceuticals. Amidst the plethora of methods

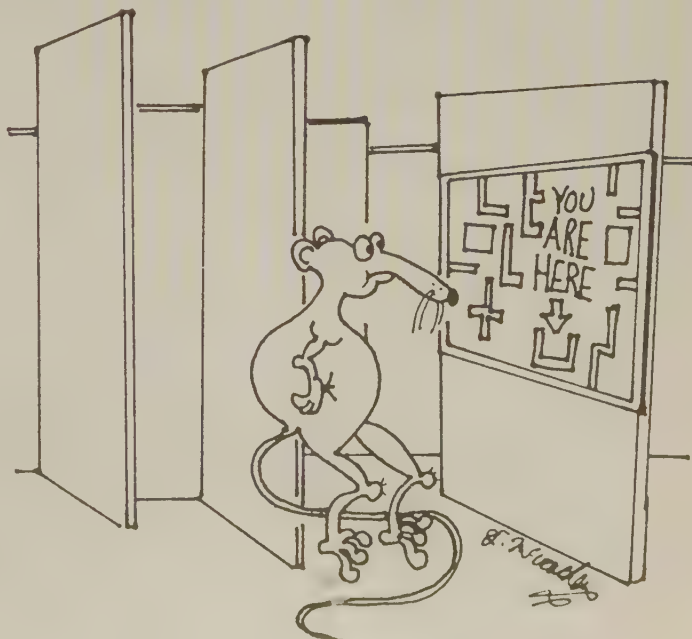
available for introducing perfluoroalkyl groups into carbonyl compounds, **trifluoromethylation** has always proved difficult. Now G.K.S. Prakash, R. Krishnamurthi, and G. A. Olah (*J. Am. Chem. Soc.* 1989, 111, 393) have harnessed a novel, efficient reagent, trifluoromethyltrimethylsilane. Catalyzed by tetrabutylammonium fluoride, it reacts with unhindered ketones to give the corresponding siloxy adduct. Hindered ketones react slowly but eventually do form the adduct. The proposed mechanism involves reaction induced by fluoride ion and propagated by the intermediate trifluoromethylated oxyanion adduct. (Thanks to Pradeep Iyer of Brea, CA, for this one.)

Add to the list of **reactions carried out in microwave ovens** the synthesis of β -lactams by "zapping" a mixture of an acid chloride with an imine and NEt_3 in DMF for 1–2 min. The synthesis of



from crotonyl chloride and an imine in pyridine took 45 s. The reactions go at 50–60 °C (Bose, A.; Ghosh, M.; Tabei, K.; Shah, M.; Manhas, M. *Book of Abstracts*, 197th ACS Meeting in Dallas, Orgn 226). (DLN)

If you need to know "**Who's Who in Technology**," here's a book to help you. It contains biographies of about 38,000 North American men and women plus indexes by geographic location, employer, technical discipline, and expertise. The expertise index is cumbersome, as the editors allowed each biographee to supply the terms; there are nearly 60,000 of them (*Who's Who in Technology*, 6th ed. Unterberger, A. L., Ed.; Gale, \$380/set, 1-800-223-GALE). (MRD)

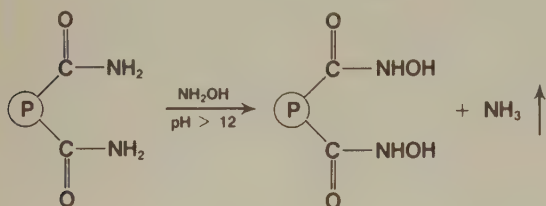


Two new mild, stable, efficient, and inexpensive oxidation reagents are reported: trimethylammonium chlorochromate (TMACC) and triethylammonium chlorochromate (TEACC) (Charya, S.P.A.; Rane, R. A. *Res. Ind.* 1988, 23, 349). In the presence of molecular **sieves in aprotic solvents** the reagents oxidize alcohol to carbonyl compounds in quantitative yields. Because of its less acidic character, TMACC oxidizes allylic alcohols to aldehydes without isomerization. (PLS)

Nucleophilic substitutions at aromatic centers are relatively unusual. G. P. Ellis and T. M. Romney-Alexander **review the various ways cyanide** can be induced to substitute for halide on aromatic nuclei (*Chem. Rev.* 1987, 87, 779). Copper cyanide is the reagent of choice, but the system is relatively flexible. (GED)

It is always interesting when a reaction can be improved by introducing a heterogeneous support. M. Kodomari, H. Satoh, and S. Yoshitomi (*Bull. Chem. Soc. Jpn.* 1988, 61, 4149) claim that copper(II) halides can be **activated by supporting them** on neutral alumina. They find that copper(II) bromide on alumina can brominate the benzene ring in toluene and other alkylbenzenes with yields greater than 85%. No coupling or side-chain bromination was observed. (HWY)

Poly(hydroxamic acid) can be synthesized from poly(acrylamide) and hydroxylamine under basic conditions at room temperature. The driving force for the reaction is the evolution of ammonia.



According to A. J. Domb, E. G. Cravalho, and R. Langer (*J. Polym. Sci.: Part A, Polym. Chem.* 1988, 26, 2623), **these polymers complex metal ions** and show biological activity. They may have uses as anticoagulants or as a treatment for urinary stones. (HWY)
(And they may be toxic.—Ed.)

How about a private corporation handling America's uranium enrichment processes? That's what was proposed by Deputy Secretary of Energy W. Hanson Moore during his July 26 testimony before the House of Representatives. Moore takes the unarguable position that a private corporation would be a lot more **economically efficient** than any government-run enterprise. He therefore proposes that a corporation be set up to handle the task of providing nuclear fuel, with the stock wholly held by the U.S. Treasury Department. Shares could later be sold to the public (without voting privileges, it is hoped).

Uranium is important to the United States: 20% of

our electricity is generated by nuclear plants; 40% of our Navy's principal combat ships are powered by uranium. (BJL)

The concept of hard and soft acids and bases (HSAB) provides a useful conceptual scheme of specific bonding interactions.

As HSAB has developed since it was first outlined by R. G. Pearson 25 years ago, it has become increasingly quantitative. Hardness is now established from ionization potentials and electron affinities. However, Pearson points out (*J. Am. Chem. Soc.* 1988, 110, 7684) that such calculations are not chemically meaningful for polynuclear acids and bases, where reactions take place not with the whole radical but at specific sites on that radical. He then calculates hardness values for these species and sites using bond dissociation information for H and CH_3 compounds. The whole list hangs together nicely. This should be a useful **tool for those who design complex organometallics** or look for ways to doctor catalyst surfaces for selectivity. (GED)

To keep faithful reproductions of antique Indian pottery from being sold as originals, Laurel and Paul Thornberg **embed the mineral scheelite**, which glows in ultraviolet light, into their clay (*DeWald, L. Arizona Highways*, August 1989, p. 21). (MRD)

Have a question about a Heart Cut item? Contact the contributing editor whose initials appear in parentheses at the end of the item; editors' addresses and phone numbers appear on the last page of Heart Cut each month.

Phone numbers in Heart Cut items (for example, 202-872-6160) are for the United States; we'd be happy to place the call for readers outside the United States who write to us.

No fewer than five communications to *Chemistry Letters* describe **oxidation catalysts** based on bis-1,3-diketone Co(II) complexes (Mukaiyama, T. et al., 1989, 449, pp. 515, 519, 569, and 573). For olefins, the oxidation site corresponds more to a Wacker reaction than to a normal autoxidation product (e.g., $RCH=CH_2 + O_2 \rightarrow RCHOHCH_3 + RCOCH_3$). A reductant may also be required. For triethylsilane, silyl peroxides are formed in near quantitative yield when the reaction temperature is lowered to 25 °C. (AJC)

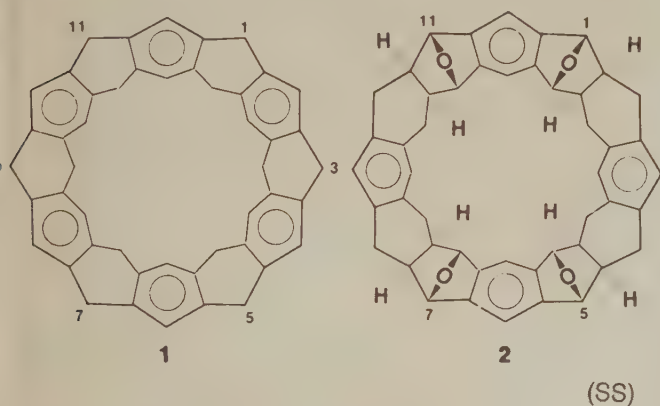
With robots doing our work, optical detectors finding our pieces, and automatic guided vehicles (AGVs) delivering our mail, many of us have asked the prophetic question "Where is all of this going?" The converse question of course is "Do the robots and AGVs know where they are going?" If your system is having trouble keeping track of where it has been and where it has yet to go, check the article by J.T.M. Stevenson and J. R. Jordan of the University of Edinburgh about their clever concept of location **detection by coded pattern recognition** (*J. Phys. Sci. Instr.* Dec. 12, 1988, p. 1140). They describe one- and two-dimensional patterned arrays in which both

incremented and absolute position information are stored on a single track. Results were impressive with positional sensitivities of a few millimeters and orientation within 0.1° . (MGT)

Continued progress in **photovoltaic efficiency** is reported by AstroPower (302-366-0400), which has produced 1-cm² cells that have 16% efficiency and 78-cm² cells with 8.5% efficiency. The cells consist of a polycrystalline Si film on a ceramic substrate. (DLN)

A typical evening at home—dinner's done, the dishes are in the washer, and it's time to take out the garbage. If you're like most of us, the moment the lid goes back on the trash can, it's "out of sight, out of mind." But each of us contributes **a ton of solid waste each year**. That's a big problem. It goes to thousands of landfills each year. The "Recycle what's recyclable, burn what isn't" approach is summarized in *EPRI Journal* (October 1988, p. 26). (GED)

Collarene is the name of a new cyclic hydrocarbon consisting of six benzene and six cyclohexane rings adjacently fused in alternating sequence (Figure 1). P. R. Ashton and co-workers (*Angew. Chem. Int. Ed. Engl.* 1988, 27[7], 966) report an ingenious synthesis of this hydrocarbon, which is a potential precursor to [12]cyclacene, a constitutional isomer of kekulene. One of the intermediates in the synthesis of [12]collarene is a molecule (Figure 2) with a celtic cross-like cavity of dimension $8.9 \text{ \AA} \times 9.6 \text{ \AA}$. This molecule traps one molecule of water that resides on the crystallographic center of symmetry. This would appear to be the first **organic analogue of a molecular sieve**.



Under the headline "Energy: Planning to Plan" K. Schneider notes:

When it was established in 1977, the Energy Department was expected to act as the government's principal Energy Research and Development Agency. But in the Reagan administration it became primarily a builder of nuclear weapons and, to a lesser extent, a research center on the space-based missile defense system. Of the roughly \$16 billion the Department will spend in fiscal 1990, about \$9.6 billion will go to its nuclear defense plants and laboratories.

President Reagan's energy strategy was simple: The market was to dictate supply and demand. At the same time, the Administration cut many civilian energy research and development programs. From fiscal year 1981 to 1989 the budget for renewable power resources like geothermal and solar energy was cut from \$630 million to \$108 million. In that period spending on improving energy efficiency and conservation fell from \$800 million to \$330 million according to the Energy Department.

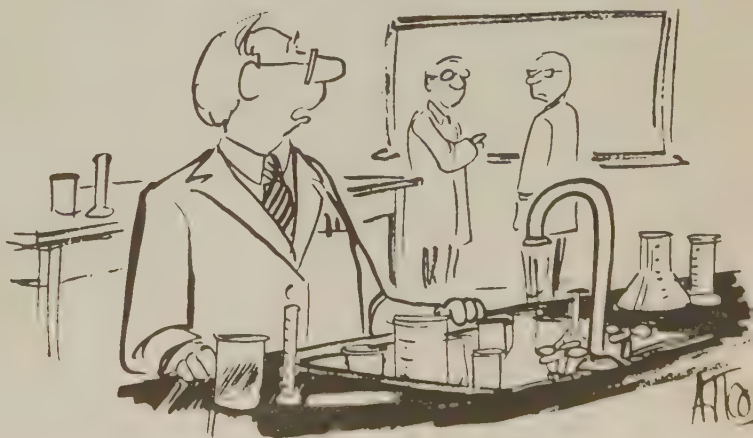
But now 9 years after Ronald Reagan vowed in his campaign to eliminate it, the Department of Energy appears to be poised to return to its original mission.

In digesting those figures it is important to bear in mind that they are current, not constant dollars, so the significance of the budgetary drops was far greater than the raw numbers imply.

To **put these numbers in perspective**, one should note an accompanying article by M. L. Wald, which notes that nearly half the oil used in the United States is imported and of that nearly a quarter comes from the unstable Persian Gulf. To protect ourselves from dislocations we have been building a targeted 90-day petroleum reserve buried in salt caverns in Louisiana and Texas. But the nearly 600 million barrels of oil stored there have cost more than \$25 per barrel (*New York Times*, Aug. 6, 1989, p. E4). (BJL)

Guess why sales of American-made single-engine airplanes dropped from 14,000 to 600 in 10 years. Strict **liability laws in the United States** did the trick. Under these laws there is no time limit on manufacturers' responsibility for their products. Too often juries made awards against producers long after the product left the factory gates. But now the worm has turned. According to *The Economist* (June 10, 1989, p. 66), the new president of Piper Aircraft has "decided to dispense with most of Piper's insurance and to fight every claim considered unjustified with a team of lawyers as fierce as 'junkyard dogs.'" (BJL)

(continued on page 28)



"Why don't physical chemists have to do dishes?"

A time for leadership

I'd like to share with you some thoughts on leadership, a quality which is all too rare in America today.

What is leadership? For most people, the definition of leadership is something like former Supreme Court Justice Potter Stewart's definition of pornography: "You know it when you see it." I think we can be more precise. Let me start with two business scenarios—real examples of real business decisions made by real business leaders.

First, assume you are the president of a company that has developed a consumer device employing a new technology. This is a promising technology, but it has limited capacity and its price, at least initially, is beyond the reach of the average U.S. consumer. You already have a successful line of tested, developed products. Do you spend more money on the untried and expensive technology, or do you put it into your established product lines?

In the second case, you are the president of a small food-processing company. You've heard about the success of marketing American convenience foods in Japan, and you want to get in on the action. You try to sell your product in Japan, but the Japanese claim it is not up to the quality standards their people take for granted. This is puzzling, because consumers here have been satisfied with the quality of the product for years. Do you abandon the Japan plan? Do you take your case to the U.S. government and ask for trade legislation? Or do you spend extra money on quality control and hope, with no guarantee, that you can satisfy the Japanese consumer?

Each scenario has a right answer and a wrong answer, and I'll come back to them later. One decision proved very right, and the other proved very wrong. The difference in each case was the quality of leadership.

The dictionary tells us that a leader is someone who shows the way. General Omar Bradley had the terrible responsibility of leading young men into battle during World War II. He described leadership as "firmness, not harshness; understanding, not weakness; justice, not license; humaneness, not intolerance; generosity, not selfishness; pride, not egotism."

Harry Truman's understanding of leadership was a bit less idealistic. He said it means getting people to do the things they know they should have done in the first place.

Confused values

The common theme in these definitions is motivation. A leader inspires others, either through instruction or example. I am afraid that the United States is losing its sense of the value of leadership. Even more disturbing than our lost sense of the value of leadership is our lack of understanding of what leadership is. America's young people want and need to follow something, but just what isn't clear. In part, we are confusing leadership with celebrity. Being famous, even if for only 15 minutes, is the goal. What you're famous for doesn't seem to matter. Even a mass murderer can turn his life into a number one best-seller.

We are also prone to confuse leadership with success. Today's idols are rock stars and athletes. I'll admit they often work hard for a living, but the mere fact that they have a hit record or can hit a ball does not qualify them as role models.



Vincent A. Sarni,
Chairman and CEO
PPG Industries

As a businessman, I am especially concerned that many of today's brightest young people are confusing leadership with wealth. Until his fall from grace, Ivan Boesky was a disturbing symbol of this misguided admiration. He was rich, so he had to be right. This Wall Street syndrome has taken hold, even in our best academic institutions.

Unfortunately, financial manipulation as an end in itself has nothing to do with leadership. It is the expenditure of great intellectual capital in the pursuit of personal enrichment at the expense of the nation's economic development. It is action without vision and fortune without foundation.

The true purpose of leadership is to shape the future instead of just taking advantage of the present. It is important to distinguish between leadership and exploitation. Leaders are devoted to improving people's lives.

Leadership manifests itself in a business in three ways. First, it inspires new ideas and inflames curiosity. Think of what Scotch tape did for 3M and you know how important it is to foster creativity.

Second, leadership promotes communication and common purpose. This is more than mere information gathering. General Eisenhower was not an inspiring field commander, but he understood how to make contentious groups keep sight of a common goal and work together.

Finally, leadership produces motivated people. Leaders are symbols as well as instructors. Think of great industrialists like Henry Ford or entrepreneurs like Digital's Ken Olsen. It is often said that you manage things but you lead people. I am absolutely convinced this is true. A technician at any of our plants can manage an expensive machine or vast amounts of information. Managing is important, but it isn't leadership. To be a leader, rather than just a manager, you have to know how to motivate people.

In business, as in any other activity, leadership involves more than position or authority. It involves values and attitudes. Knowledge and numbers go only so far. Effective leadership requires something internal, something intangible. The Greeks had a word for it: virtue.

The attributes

A true leader is possessed of virtue. That is easy enough to say, but what does it mean? Based on my experience, I would identify seven attributes of virtuous leadership:

- integrity, because trust is the bond of collective effort;
- vision, because foresight is the path to the future;
- courage, because belief in one's vision is the engine of progress;
- perspective, because a broad view is the assurance of relevance;
- flexibility, because adaptation to circumstance is the springboard of innovation;

- responsibility, because a sense of accountability is the guarantee of quality; and finally,
- wisdom, because an understanding of human nature is the key to persuasion.

Everyone possesses these qualities in some measure. An effective company has a clear sense of direction and a respect for its people. At PPG, we regard every person as a manager. Every one of our 36,300 people is responsible for the performance and the welfare of the company. Our senior executives have to keep that in mind as they help the people under them grow professionally. I advise them to talk to their people about their aspirations and help them nurture their talents and skills. Teaching and nurturing are essential functions of leadership.

Strong, effective, compassionate leadership can and will make a difference for this country. The easy way out is to say global competition is too strong and unfair, and to abandon the industrial base of this nation. This is a dangerous approach. America cannot survive if its leaders are content to leverage the nation's wealth and become Wall Street gentry.

Nor do we have to do this. The American GNP has a more solid base than paper deals and speculation. Manufacturing is not declining as a percentage of GNP, relative to the "golden age" of the post-war boom. In 1947, manufacturing was roughly 22% of the GNP. It remains 22% today. With the resolve, the skill, and the wisdom to be effective leaders, we can preserve and strengthen the industrial base of the United States and withstand the pressures of global competition.

I haven't forgotten my quiz. The first case involved RCA and Ampex, and the product was the home VCR. Their early model had a taping capacity of only one hour and did not do well in preliminary market tests, so they abandoned the project. Now VCRs are a \$6 billion-a-year business, and not a single one is made in the United States.

The second case concerned Weaver Popcorn Company in Indiana. After the Japanese complained about the quality of the popcorn, its leadership spent \$1 million on an optical scanner to sort the kernels better and meet Japanese quality standards. Weaver now has 60% of the Japanese popcorn market.

The global marketplace awaits us. Instead of resisting it, we need to become a full partner in its exploration. Instead of begrudging the people of developing nations their jobs, we need to turn their improved living standards to our advantage. We can do this if our public and private leadership has a clear sense of direction and the capacity to inspire us to do the things we know we should have done in the first place.

Adapted with permission from a commencement address at the Carnegie-Mellon University Graduate School of Industrial Administration, May 1988. Copyright 1988 PPG Industries, Inc.

Ten ways to

Daniel Best

After a year, only about one in 10 new product entries has survived the marketplace, and that doesn't count the products that got shelved after filtering through corporate conceptualization, prototyping, consumer testing, production scale-up, and marketing channels.

Not only do many bad ideas make it to the marketplace; many good ideas never leave the lab bench or are withdrawn before they are tried.

Any number of pitfalls in the product development process can "deep-six" a product. Let's look at some ways to keep that from happening to your product.

Although I focus on consumer products, what I say applies to all efforts to convert an idea to a commercial product.

1. Overlook key product attributes. Rarely do products appeal to customers because of a single attribute. More often their appeal is based on specific combinations of attributes such as taste, aroma, texture, color, packaging appeal, convenience, and appeal to status or ego.

During zealous efforts to meet specific development objectives, important product attributes often are overlooked. Ultimately consumers can just as easily pass judgments on products by what they don't like about them, such as soft-textured cookies with insipid flavors (ugh), "health" snacks, cookies with impossible-to-open packages (scratch the elderly market!), and frozen pizza with a tarragon flavor profile (now defunct).

An alternative approach is that of total concept engineering (TCE). Essentially, this approach consists of four steps:

- Begin by defining all consumer-relevant product features before prototype development by careful consumer testing and evaluation of similar products on the market.
- Engineer the desirable attributes into product prototypes (packaging, color, flavor).
- Consumer-test initial prototypes to find out how they match consumer needs and perceptions (i.e., identify what is wrong with the project).
- Take the consumer inputs, go back, and fix what is wrong. Any one of those "wrong" attributes can turn the consumer off, regardless of the many positive quality attributes.

Although trade-offs may be inevitable, all product quality variables merit consideration.



2. Overlook the resource network. As a 25-year veteran of product development once remarked, "90% of all product development is phone work." The best, most obvious, and usually underutilized resource available to product developers is the supplier community.

Most suppliers are highly experienced individuals with long histories in product development. Many supplier companies maintain extensive application lab facilities staffed by personnel with longstanding experience in formulation and processing.

Don't overemphasize confidentiality. Indiscreet individuals or companies soon make themselves known, while truly professional sales representatives eventually deduce what's up anyway. Minuscule risks of leaks are balanced by the time and resource savings gained by tapping into existing and available sources of technology.

Often in-house resources remain unrecognized or ignored. When "competing" in-house groups erect secrecy barriers between themselves, duplication of effort is ensured. A major part of successful product development remains proper information management—a skill that few companies offer in training.

3. Cut costs to reduce quality. What often happens in the product development process is as follows: A new product prototype that tastes, looks, and smells great is developed. At the last moment, as planning is under way for plant start-ups, those horrible words from marketing come back: "We've got to cut costs."

This is the beginning of the end. Ingredient and packaging material costs (and usually quality) are shaved from the product, and the results are sent out once more for final consumer testing to reassure marketing that, yes, it truly is the same product. Failing the first test, it may be tested again and again until the correct answer is obtained.

Minute qualitative differences in a consumer test atmosphere that is free from competitive product influences are hard to measure. If the product is subjected

ill a project

to a string of cost reductions, each test can register "statistically insignificant" differences in product perceptions within "experimental error." Unless testing is done against the original product, however, cumulative statistical "no-differences" can be very different from testing the final product against the original one.



The phenomenon is pernicious. Cost reduction over time gradually chips away at a product's "quality halo," until an Achilles heel is exposed and competitors reclaim the quality high ground.

Cost cutting on quality control is another easy trap to fall into. Measurable returns on quality control programs are hard to obtain. The output of defective goods may be "statistically insignificant," but loyalty lost can be very real, permanent, and pervasive. Consumers don't have to give any product a second chance. Processors can't afford to hope for one.

4. Misapply resources. New products require time, labor, and capital. Misapplication of these resources can result in misplaced funding priorities or uncertainty about project commitments.

Investing in highly specialized processing systems closely married to a single product line is risky and expensive. Alternatively, investing in processing systems for their versatility beyond immediate project requirements helps diffuse investment risks. This, in turn, reduces a project's financial risks. Forecast how your new process will apply to your next generation of products.

Labor allocations can be critical in project success rates. Labor resource investments should be commensurate with



expected returns on investment. A "cold feet" approach may be to limit, or spread out, labor resources over a wide range of opportunities to limit the risk of failure. Essentially, this only serves to minimize the risk of success, ensuring that the initiative will either founder in disinterest or go to a better funded, more committed competitor.

For example, a tremendous market opportunity exists for any company that could develop a palatable, non-sodium salt replacement. Will the initiative go to a company that commits a fully staffed research team to the effort, or to the one that assigns the project to one scientist part time, with instructions to "look into it"?

5. Misuse consumer test results. The popular refrain along each step of the product development process is "Let's consumer test it." No argument there.

Several considerations are worth noting, however. Some view consumer tests as black-and-white decision-making tools. Wrong, wrong, wrong! Consumer tests only serve to differentiate between shades of gray. For example, a consumer test result obtained within an 80% confidence limit means that there is a 20% chance of drawing the wrong conclusion.

Sometimes products tend to be consumer tested every time R&D changes the color shade or flavor profile. Odds are that eventually a product will fail consumer testing (i.e., eventually you will hit that 20% chance of reaching a wrong conclusion), generating a sigh of relief in certain quarters.

Consumer testing is only partially successful at minimizing the infinite numbers of variables impinging on consumers' value judgments. Consumer test results may help define the focus of new product debate, but they are no substitute for risks taken on the basis of common sense and experience.

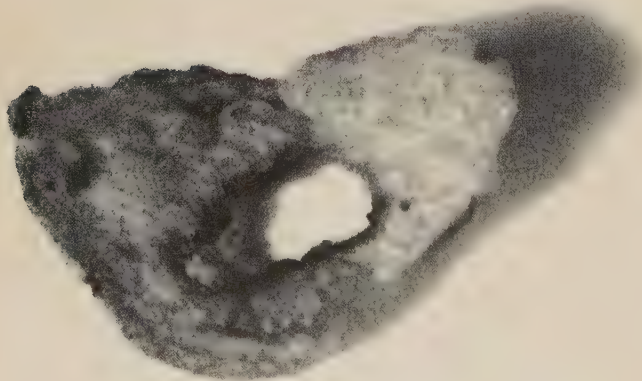


6. Take costs at face value. If new product or technology cost projections come in too high, a risk avoidance management may kill a product right then and there. Aggressive determinist managers, on the other hand, will do two things: First, they will reexamine the presumptions upon which cost structures were based, and second, they will seek ways to bring costs in line.

Labor, ingredient, processing, packaging, and distribution costs are all variables that bear constant reexamination. Presumptions upon which the original cost structures were based may be out of date. If ingredients are priced too high, are lower cost sources available? If processing costs are too high, are alternative, cheaper processing methods available? Is copacking a lower cost alternative?

Are there other market segments to which the product concepts can appeal, and consequently increase volume projections? Was the projected price for a product too low?

All these factors bear constant reexamination.



7. Lack of commitment. We can see lack of commitment in many ways. It can show up as a lack of focus, where constantly changing signals or erratic funding from above can leave product developers and marketers merrily dancing in and out of developmental cul-de-sacs.

Projecting investment returns beyond the near horizon or payback hurdles using discounted cash flow and

product life cycle projections can help put short-term product performances into perspective. The appropriate response to consumer test failure is often to go back and fix the products, not to walk away from them.

One of the key qualities that has enabled the Japanese to penetrate new markets successfully has been their tenacity, that is, their focus on strategic objectives and their long-term commitment to achieving those objectives. Good examples of commitment to new products and technologies are Procter & Gamble's Pringles potato chips, which finally turned a profit in 1988 after 10 years of struggle; the aquaculture (fish farming) and surimi-seafood (seafood analogue) industries—centuries-old industries that are flexing their technical muscles in the face of booming seafood prices; and the consumer microwave industry, which hit its growth spurt 30 years after its birth in the early 1950s.

Of course, that is not to say there isn't a time when one should cut losses and seek new directions.

8. Overlook the time factor. A key component of strategy has always been timing.

Products can languish eternally in the lab or pilot plant while product development personnel nit-pick with marketing over color shadings and flavor nuances until, much to everyone's surprise, a competitor jumps in and takes the marketing initiative. Still other products are rushed into the marketplace before their quality attributes have been properly refined. The outcome can be many disappointed customers. You can lead customers to product trial, but you can't make them repeat buy.

Sometimes good ideas can be passed over while decision-makers wait for consumer tests to identify "the big one." Some decision-makers have been known to wait for years—never mind the economic losses incurred from not pursuing some of the smaller ideas. Many currently big successes such as microwave ovens and yogurts started out as small ideas.

One suggestion to circumvent this problem is to combine a TCE philosophy with an assumption that at least one other company is working on the same product. Usually you will be right—they read the same consumer data, after all.

9. Tactics and strategy. "A common mistake is to mistake tactics for strategy," the president of a major national restaurant chain once remarked to me.

Focusing on tactics excessively can leave organizations floundering for strategies to fit. It should be the other way around.

"The proper way to approach strategy development is to first define what the corporation's strategic objectives are,

and then determine the best way to achieve them," observed a Campbell Soup Co. vice president.

Irradiation, controlled atmosphere packaging, and frozen distribution systems are all tactics. Products, or markets, targeted by a corporation are objectives, while technology, marketing, advertising, distribution, and a host of other factors are components of strategies designed to obtain the objectives.

Thus, for a processing company to make a decision to focus upon irradiation technology, biotechnology, or aseptic products would be to define a tactical objective, rather than a clear, strategic objective.

Overemphasizing tactics without a strategy or objective can result in good products that don't fit consumer or corporate needs.

10. Manage by avoidance. The pernicious anemia of new product development is the corporate malaise that manifests itself as "managing by avoidance" (let's call it MBA_o). This is the most difficult product development hurdle to overcome.

MBA_o symptoms can include an overreliance on consultants to make decisions or a tendency to accept projections, estimates, and opinions at face value. Failures are greeted with a shrug rather than being readdressed and fixed. MBA_o can mean indecision translated into flurries of memos, commissioned studies, and rationalizations for inaction. It can mean surrounding oneself with the trappings of technology without the slightest inclination to use it. An example of this could be General Motors' rush to automate before deciding just what that automation was supposed to accomplish. Project responsibilities are minimally addressed and shoved up, down, and sideways

into bureaucratic black holes of indecision to the tune of "it's not my job," and "it's their responsibility."

Risk avoidance managers have been known to breathe sighs of relief when products fail consumer tests, as complex career-threatening decision hurdles become moot. "We did our best" is the standard MBA_o riposte to failure.

These are symptoms of a tired company, lost initiative, or an accountability-reward structure that is out of whack. If rewards for success are low and/or the price of failure is derision and a ruined career, risk avoidance management becomes the path of least resistance. In ossified bureaucratic decision-making structures, individuals can function quite successfully as risk avoidance managers by following protocol and abdicating accountability to the "system."

Ultimately, however, the rewards go to the risk-takers. All too often, this point is conveniently overlooked.

Adapted from "10 Ways to Kill a Project," which appeared in the February 1987 issue of *Prepared Foods*. Copyright Gorman Publishing.



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SOCIAL LAWS

The Law of the Letter: The best way to inspire fresh thoughts is to seal the letter.

Arthur Block, in his *Murphy's Law, Book II*

COMMODITIES?

No longer is any market or product mature—another reason for the surge of newcomers even in old industries like steel or retailing. All are immature, all being redefined, fragmented and customized. Convention talks of "niche markets." In fact, there are no non-niche markets any more.

Tom Peters

SIGNIFICANT DIFFERENCE

There are 13,000 Japanese doing research in the United States in government and university laboratories. Only about 500 American scientists are working in Japan. "It's partly cultural," says Sen. Jay Rockefeller (D-W.Va.), who just returned from Japan. "They have never been in a position of opening up their country in large ways."

The two most important obstacles to improving scientific exchange with the United States is the language barrier and housing, said Hiroshi Inose, director-general of Japan's National Center for Science Information.

The value of the yen and skyrocketing real estate prices are making it harder to pay for American researchers in Japan.

Associated Press

Cooperative R&D ... in Japan

George R. Heaton, Jr.

We can learn a lot about cooperative research from the Japanese, but only if we understand why their system was conceived, how it works, and how it is changing. Otherwise we run the risk of designing our own emulations that are ill suited to our conditions and needs.

The cooperative research system is a relatively recent phenomenon in Japan. Modeled on a British World War I program, the system was inaugurated in 1961. The law provided the legal framework for the formation of cooperative ventures known as technology research associations and addressed three major systemic problems faced at that time. One was the absence of neutral forums for technical communication across industrial groups whose traditional rivalries had inhibited technology transfer. A second issue was the need to relegitimize government support for business, which had become suspect as a result of the pre-World War II military-industrial complex. The third and most obvious problem was the relatively backward state of Japanese technology.

In the early 1960s, catching up with the West was the imperative that guided all aspects of national policy. For the most part this did not mean developing new technology; rather, it implied transferring foreign technology to Japan, adapting it, and diffusing it throughout industry. It was largely for carrying out this last task, diffusion, that technology research associations were conceived. Medium-sized enterprises were initially singled out for membership because their productivity, generally low, could readily be increased if they adopted state-of-the-art manufacturing techniques already in use elsewhere. This strategy promised to improve the competitiveness of Japanese industry in international markets within a short time. Over the longer term, cooperative research was intended to attack a different problem—the low levels, or absence, of R&D in many Japanese companies. Cooperative ventures would act as a catalyst to private R&D by bringing new firms into the research system and multiplying the effectiveness of their small research budgets.

Since the inception of the system, some 80 technology research associations have been established. Most of them come under the aegis of the Ministry of International Trade and Industry (MITI), although sponsorship of cooperative research has by now become a standard mode of operation throughout the Japanese government. In general, these ventures are quite modest in scope. For example, MITI's Biotechnology Research Association—which focused on recombinant DNA techniques, bioreactors, and large-scale cell culture—involves 150 researchers at 14 companies (mostly chemical manufacturers, but also some food-processing companies and a pharmaceutical firm). Its annual budget is only about \$4.5 million. A similar association under the

Agriculture Ministry has 16 members and a budget of less than half a million dollars.

In addition, most research associations have no physical premises. An administrative headquarters may be furnished by a "lead company" and staffed by an executive director—usually a retired official who has entered the private sector—and a few support personnel. The primary work of the associations is information exchange and mutual coordination of a small research agenda, not actual performance of research projects. For that reason, the research itself is almost always conducted in member firms' facilities by their own personnel. The events of greater technical importance are meetings of association subgroups in which small numbers of researchers working on similar topics report on progress, present data for discussion, and consider next steps.

Through private legal entities, the research associations are financed in large part with public funds. This support takes the form of either a research contract or a forgivable loan. In the former case, the government owns the research results but typically licenses patents back to the association on favorable terms. When funding is extended through forgivable loans, the association owns the technology but must repay the loan if the project is "successful." Public funding is supplemented by member contributions, but these typically cover administrative costs only, not research.

Besides providing financial support, the government promotes technology research associations through favorable tax and regulatory policy. For example, a member firm that buys equipment for association use may depreciate it faster than if it had been bought for internal use. And although the Japan Fair Trade Commission—analogue to the U.S. Federal Trade Commission and the Justice Department's antitrust division—must review an association's format and activities, the commission's role is informal and consultative more than regulatory or coercive. Officials sometimes suggest changes in a research association to prevent anticompetitive practices, but the regulators and industry always seem to reach an accommodation. Thus far there has been no litigation on this issue in Japan.

Cooperative ventures would act as a catalyst to private R&D by bringing new firms into the research system and multiplying the effectiveness of their small research budgets.

This kind of friendly interaction between government and industry sustains a technology research association throughout its development and life. Often the association has its genesis in parallel public and private initiatives. For example, a business organization like the *Keidanren* (the Federation of Economic Organizations, the largest and most influential business group in Japan) may form a committee to look into a particular industrial problem or emerging technology. The government might also set up a study group to examine the same issue. The two parallel groups typically conclude that it would be beneficial to devote a research association to this problem or field. Once a general technical focus is established, the government issues a solicitation and then awards contracts or loans—almost invariably to the firms that initially persuaded the government to mount the program. As one MITI official put it, new initiatives “percolate” simultaneously in government and industry.

Once it is under way, an association provides a general forum for government–industry communication, a critical element of MITI’s industrial policy. Many mechanisms are used: advisory committees, periodic written reports, and the constant interaction between the association and its official sponsors. In addition, association members communicate freely with experts at universities and government labs.

It can be done

A few years ago, U.S. companies saw little need for joint research, and in any case public policy was not designed to support it. The example of Japanese success and the need to respond to increasing international competition, however, has cast cooperative R&D in a new light. Today, as U.S. industry tries to recreate this chapter of the Japanese success story for itself, the government has begun an about-face and is more willing to help.

Revised tax policy, for example, has created a favorable climate for a unique form of cooperation, the R&D limited partnership. Originally, R&D had been deductible only when it was undertaken to improve an existing business. But a 1974 Supreme Court decision extended the R&D deduction to new jointly funded research concerns, even if the R&D they performed was not related to the ongoing business of the firms or private investors that started them. By the mid-1980s, hundreds of R&D limited partnerships had been established, with total funding reaching several billion dollars.

The end of 1984 marked the beginning of a new era in U.S. policy toward cooperative R&D. First, Congress passed the National Cooperative Research Act, ridding antitrust laws of ambiguities that had made the business community reluctant to engage in joint R&D and removing the specter of triple damages in the event of

The Japanese experience shows that a successful cooperative research system requires a delicate balance between government support and industry leadership—a balance that the United States has yet to achieve.

liability. More than 50 R&D consortia have been founded under this act. About a year later, the National Science Foundation began funding Engineering Research Centers that linked universities and industry in cross-disciplinary research.

In 1986 Congress passed the Technology Transfer Act to encourage cooperation between industry and the national laboratories and enacted a Basic Research Credit to encourage industry funding of university research. Most recently, the 1987 congressional funding of Sematech, a research consortium to improve semiconductor manufacturing, indicates Washington’s willingness to expand the boundaries of public–private cooperation and, for the first time, to provide significant direct financial support.

Lessons for the United States

In this climate of enthusiasm, some words of caution are in order. While the Japanese experience as a whole offers strong support for the concept of cooperative R&D, it also reveals some of the concept’s inherent limitations. It is not enough for U.S. companies to realize that the conventional wisdom about Japanese R&D is fraught with misconceptions (Table 1). They also must understand why the system is more modest and less ambitious than commonly supposed. Moreover, the Japanese experience shows that a successful cooperative research system requires a delicate balance between government support and industry leadership—a balance that the United States has yet to achieve.

To begin with, it is not because the Japanese are weak innovators that their technology research associations focus on generic research and diffusion of information instead of on work that yields important, immediate technical or commercial outputs.

Any enterprise that brings competitors together is bound to be marked by a certain gamesmanship. In forming a research association, for example, the Japanese government and the leading industrial proponents try hard to attract the best firms to participate. Unfortunately, lagging firms are usually the most eager to join, and sometimes the technical leader will refuse, for obvious competitive reasons. The same kind of dynamic resurfaces when research subgroups are formed and projects chosen,

Table 1. How it doesn't work

Misconception	Truth
Research associations dominate Japanese industry.	90 % of cooperative ventures are private contractual arrangements between two parties, and most involve companies that are already affiliated.
Public funding is a major incentive to cooperation.	The real reasons companies participate are efficiency in solving common problems, fear that by not participating they might miss out on important technology or information, knowledge of government officials and programs, and access to intelligence on research in other companies and universities. Companies also join to have their technical work critiqued by colleagues in the industry.
Cooperation produces commercially significant products or technology.	Instead of attempting to generate marketable processes, they usually concentrate on diffusing technology and techniques and gathering information about what won't work.
Government sets the agenda for industrial research.	Government officials function more as conveners, mediators, record-keepers, and administrators than as planners.
Japan's research system is monolithic.	MITI is not the only organizer of industrial cooperative research; several ministries compete to establish research consortia.

as each firm tries to maximize its advantage at the expense of its competitors.

As a practical solution, then, the associations tend to pursue nonthreatening and often low-priority projects. Without a doubt, there is good research being conducted, but it tends to be incremental rather than radical, and remote from the commercialization process. The desire is to enhance the knowledge base underlying the next generation of technology but to leave the development and production of that technology to private efforts.

Americans often point to the success of Japan's very-large-scale integration (VLSI) project of the late 1970s and early 1980s as proof that cooperative research produces major technological advances. But it should be noted that this project was highly atypical in that it was mounted in response to an immediate foreign threat—developments at IBM. Five computer and semiconductor firms received generous funding—\$280 million from MITI and \$80 million from Nippon Telephone and Telegraph—to perform intensive research together in a single facility. The project had clear technical goals: development of 1- μ m device technology, submicron process technology, and 64K-bit dynamic memories. Typical projects involve much less money, more participants, more diffuse technical goals, many research sites, and a less immediate market challenge to participants.

Just as the competitive dynamic restricts the scope of the work that can be performed in R&D consortia, so does it appear to place practical limits on the organizations' sizes. As membership increases, the difficulties in agreeing on a technical agenda rise proportionately; the larger the group, the less ambitious and more basic the research aims tend to be.

The Japanese experience also suggests that research consortia are not the answer for all industries. Two basic situations call for joint R&D: when members of an industrial group face common technical problems and when institutional barriers hamper efforts to solve them

through individual efforts. Sematech seems to meet these requirements. In the first place, chip manufacturing expertise is a problem most semiconductor firms are facing. In the second place, the structure of the industry seems to limit the resources available to attack it. U.S. chip manufacturers are relatively small specialized firms with limited R&D funds.

Similarly, in the case of NSF's Engineering Research Centers, a new, cooperative institutional form may be able to bridge gaps between engineering disciplines and between industry and academe. But for an industry such as software development, an area of American excellence that is extremely diverse and that already enjoys good channels of information transfer, joint R&D would probably have little to offer.

Besides giving an indication of what U.S. industry should and should not expect from joint research, the Japanese model demonstrates the importance of active government support. One key government role is to provide part of the funding. Those most in need of joint R&D—small and mid-sized manufacturing enterprises—are unlikely to do it without the stimulus of public monies. Government funding is justified because the benefits that joint research yields to the group as a whole, and to society at large, can exceed the benefits to any individual participant. But this funding should be a catalyst, not a subsidy, and thus should be small and widespread.

An equally crucial government role is to build institutions that allow cooperative research to flourish. For too long in the United States, the relationship between government and business has been adversarial, acted out in legal and political dramas in Congress, regulatory agencies, and the courts. The kind of public-private dialogue that generates and sustains institutions for joint R&D in Japan would do much to ease the strain between government and business in the United States.

The NSF Engineering Research Centers, which provide long-term institutional funding, provide one valuable step

in this direction. The recently organized National Center for Manufacturing Sciences offers another. But further measures are needed. The Trade and Technology Competitiveness Act of 1988 established the National Institute of Standards and Technology and authorized it to fund joint industrial research. Unfortunately, no funds have been appropriated for this essential mission. In fact, it appears that ongoing programs funded by the Department of Defense, such as Sematech or high-definition television, are in danger of drastic cuts in funding.

But if the Japanese experience shows that a strong government presence is necessary, it shows just as clearly that the public role must be carefully circumscribed. Above all, publicly supported cooperative R&D must take its direction from industry. The U.S. government may have much more depth of technical expertise than the Japanese, but it still cannot presume to know what industry needs. If it makes sense to provide public support for cooperative industrial R&D, it also makes sense to trust the technical implementation to industry.

Adapting to change

Of all the lessons the United States can learn from Japan's research experience, one stands out as all-important: A research system must be flexible. It must be able to react quickly to changing market conditions, and it must be sensitive to the strengths and weaknesses of its constituents. From the start, Japan has implemented cooperative research with the goal of flexibility in mind. Because the research associations, for the most part, have small budgets, short life spans, and minimal facility and personnel commitments, the system as a whole has been able to adapt readily to the priorities of the moment.

Today, the needs of Japanese industry are changing so rapidly that they are straining the research system's ability to adapt in its current form. The biggest change of all has been the rise in Japan's technical prowess relative to the rest of the world. As the world's second-largest R&D performer (having surpassed the Soviet Union in R&D spending in 1987), Japan is now as much the source as the adapter of new technology. In many fields, Japanese companies are on a par with or ahead of foreign competitors. And they have much larger internal R&D budgets than before. As a result, publicly supported cooperative research has become a less significant element of firms' technology strategy. Moreover, the traditional aim of cooperative research—catching up—is rapidly becoming irrelevant.

The Japanese government is experimenting with new institutional forms that put a higher premium on creativity and provide greater freedom from bureaucratic control. In the area of cooperative research, the most significant new undertaking is the Japan Key Technology Center (Key-TEC). This program was developed largely as a response to

the argument that the "nonprofit" technology development pursued in research associations does not breed innovation. Not only are the joint ventures it funds expected to commercialize the technology they develop, but also Key-TEC itself is supposed to operate profitably over the long term, like a private venture capital company.

Because of these rapid changes in goals and institutions, Japan is a moving target, and the organizational structures that the United States is trying so hard to duplicate may soon be obsolete. Thus the United States cannot simply mimic the cooperative R&D policies that have worked for Japan in the past. Instead, our policies must be designed to capitalize on our own strengths. University-industry cooperation and technical entrepreneurship stand out as areas in which the United States has been uniquely adept. R&D limited partnerships, moreover, have no analogue in other countries. We should better support such initiatives through favorable tax treatment for cooperative forms.

Whatever policies we enact, however, the R&D organizations that result from them should be lean enough that they can easily be reoriented or, if necessary, disbanded. Each venture should be seen as a modest experiment. We should not lock ourselves into large-scale projects but should instead encourage the development of a widespread, decentralized, evolving system of cooperation among firms and between the public and private sectors.

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Problem solving: The combined approach

Part 5
Hubert M. Hill

A problem is an unsatisfactory situation that we decide to remedy. Different types of problems demand different approaches. We can identify these types of problems by the questions that are being asked and by the solutions that are being sought (Table 1).

In the previous parts of this series (1-4), I have presented problems as though they were clean and simple. Actually, they are fuzzy and complex. It is not always obvious which system has the problem or which approach should be used to solve the problem.

Problems seem to change their nature as we go about solving them. To test a prediction in the research approach, we design and run an experiment. The key word is design. This tells you to switch from the research approach to the design approach. If the experiment is complex, we may have to develop procedures to ensure that it is run correctly. This is a control situation, and another approach switch occurs.

Figure 1 illustrates the movement among approaches. Note that approach switching can happen at many points during problem solving. The key is to ask the right questions and to evaluate the situation after each step. To

prepare the plan of attack for each step of each approach, we use the design approach.

The following steps can be used for problem solving. They combine the three approaches as needed in the problem solving process.

1. Identify the system involved and determine its purpose.
2. Gather information about the nature of the problem.
3. Choose an approach.
4. Plan your attack by using the design approach.
5. Do the first step of the chosen approach.
6. Evaluate the results of step 5.
7. Decide to continue or return to step 3 on the basis of the evaluation.

The approach chosen will depend partly upon the ultimate objectives of the improvement and on the system to be improved. If the customer wants an improvement in some characteristic of the output, you will probably start with the research approach. However, if the problem is general improvement of a manufacturing process, you might better start with the control approach, even if the system is in satisfactory control. The first step of the control

Table 1. Identifying problem types

Question	Steps to be taken
Design approach "How do we do this?"	Define the purpose to be achieved. Plan alternative (ideal) solutions to achieve the purpose. Analyze the solutions and choose target to be designed. Design the details of the solution. Implement the solution. Evaluate the results.
Control approach "How do we ensure that the process runs as intended?"	Determine the requirements and characteristics of the system. Determine variables to be controlled. Develop measures and standards. Develop counteractions. Implement and test the controls.
Research approach "How do we test this?"	Develop hypotheses to explain the facts. Make a prediction based on these hypotheses. Test the prediction with an experiment. Decide to accept or reject each hypothesis.

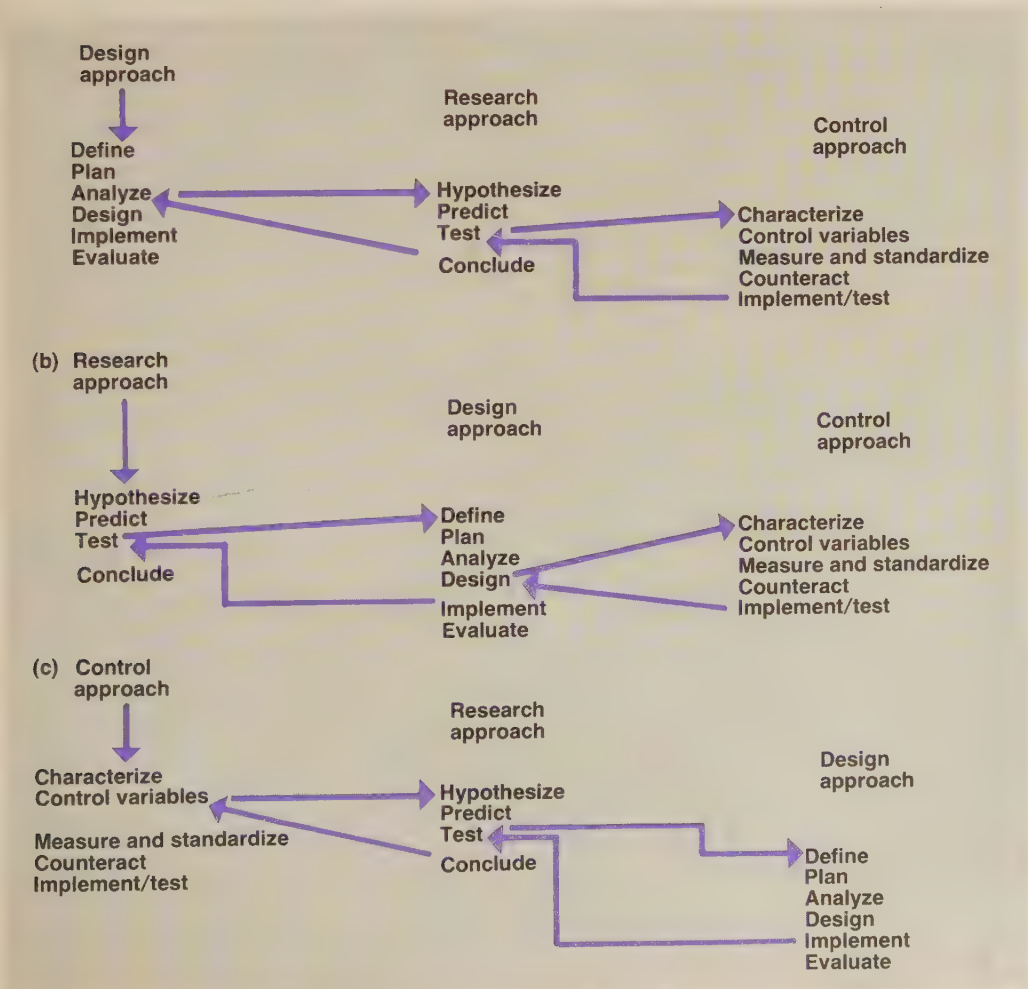
This is the fifth article in a series on problem solving. The first four parts appeared in 1989:

- 1 March, p. 148
- 2 May, p. 289
- 3 July, p. 403
- 4 December, p. 754



approach will list things you know, things you think you know, things you aren't too sure about, and things you don't know about the system. Then the research approach can be applied to learn how to improve the process. In service systems, customer complaints may indicate a desire for new features or improved accuracy or timing. These problems will need the design and control approaches.

Living is change. We and our systems must change or be pushed out of the mainstream of activity. Problem solving does not exist in isolation but is part of a process to develop or improve systems. We can solve problems as they appear or by anticipating them and solving them before they appear. "If it ain't broke, don't fix it" must give way to "Continue to make it better, before it breaks."



Systems improvement is a journey, not a destination. It is a continual process, with no end, because improvements in knowledge and skills lead to improvements of systems. As products or services become obsolete, it will be necessary to abandon some systems and design new ones to provide new products or services. Then a new cycle of improvement will begin.

This continual cycle of improvement includes all products and processes and the ability of an organization to improve its processes and products. About 80% of the problems in an organization are systems problems that are the responsibility of management, which controls the necessary resources. If continual improvement is to succeed, the workers must be given the opportunity and resources to solve the problems.

The improvement cycle

Depending on the situation, the improvement process may start in any of the three ways shown in Figure 2.

When using the design approach (2), we pick an ideal system to serve as a target for the design of the real system. Theoretical systems serve as research projects for future new systems. The matrices of each new or improved system show the flow of improvement toward the ideal future system (Figure 3).

To remain competitive, organizations must strengthen both their ability to find opportunities for improvement and their ability to enhance products and processes.

An expansion of the design approach can be used to describe an organization. A hierarchy of purposes shows how the systems are interconnected and describes what gets done in each system (Figure 4).

To develop the purpose hierarchy we must know the output, customers, and input of the system. The purpose is to produce the output. The next higher purpose is to know how the customer uses the output. The input comes from the previous system. From these, you should be able to develop the purpose hierarchy that describes the organization.

Every system has customers. Some are easily identified; others are not. Things happen through a chain of systems with their succession of customers. Managers tend to think only of external customers, but if the manager's job is to facilitate the work of the employees, then the manager's customers include the workers in the organization. A college's customers include the people who hire their graduates and the potential students who may attend the college. The chemistry department is the customer of the math and physics departments, which teach prerequisite courses. The chemistry instructor's customers are the students in the class.

Sometimes inputs and outputs appear to be the same. New students are inputs; students with new knowledge are outputs. A piece of electronic equipment can be an input to

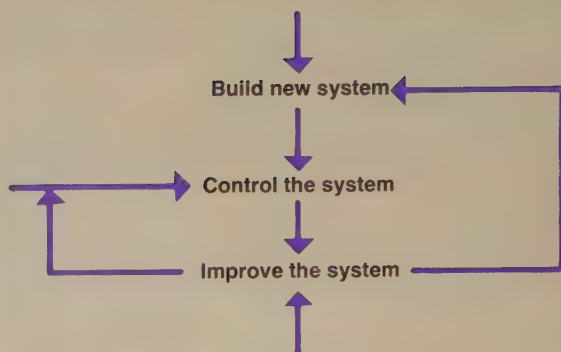


Figure 2. Improvement cycle

a maintenance system; the repaired equipment is an output.

The output of any system goes to a customer. If the output is to represent quality to the customer, it must not cause the customer problems. You must know who the customers are, understand how they use the output, and know how they feel about the product or service received. An output that causes the customer a problem represents an opportunity.

Continual improvement involves two basic steps: finding opportunities and using them in a continual cycle of improvement for every system in the organization.

Problems are usually expressed as symptoms of something that is happening within the system. A toothache may be the symptom of a cavity, which a dentist can fix. A polluting effluent may be caused by excess solvent, which might be amenable to recycling. Symptoms represent opportunities for improvement. These opportunities are points of concern or dissatisfaction to customers, management, or workers. These concerns may be caused by a need for improved quality, lower costs, increased production, or the availability of new technology. Most opportunities for improvement appear at the interface between systems or between elements within a system. Opportunities can exist in satisfactory and unsatisfactory systems. They also may indicate the absence of a system to produce a new product or service. Opportunities become projects when management commits resources to finding a solution.

Ideally, we shouldn't have to wait for someone to complain or to suggest an improvement. What's needed is a regular program for examining each system by asking "How can we improve this system?" The best people to ask are those who operate the system and those who interact with the elements of the system. Opportunities also may be found in asking why any event happens. Opportunities should represent some added value to the customer. We need some measure of the importance of each suggested opportunity to rank them before choosing specific projects. The opportunity list should be updated regularly because it may change with time.

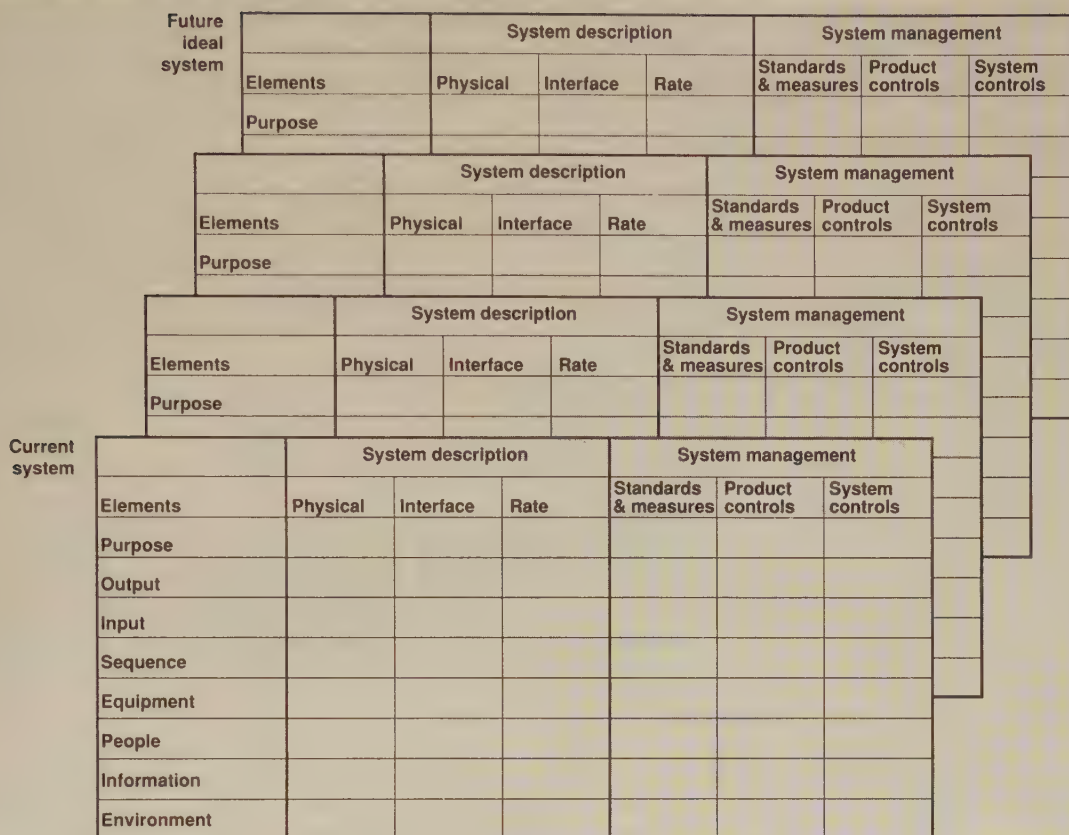


Figure 3. Time sequence of matrices

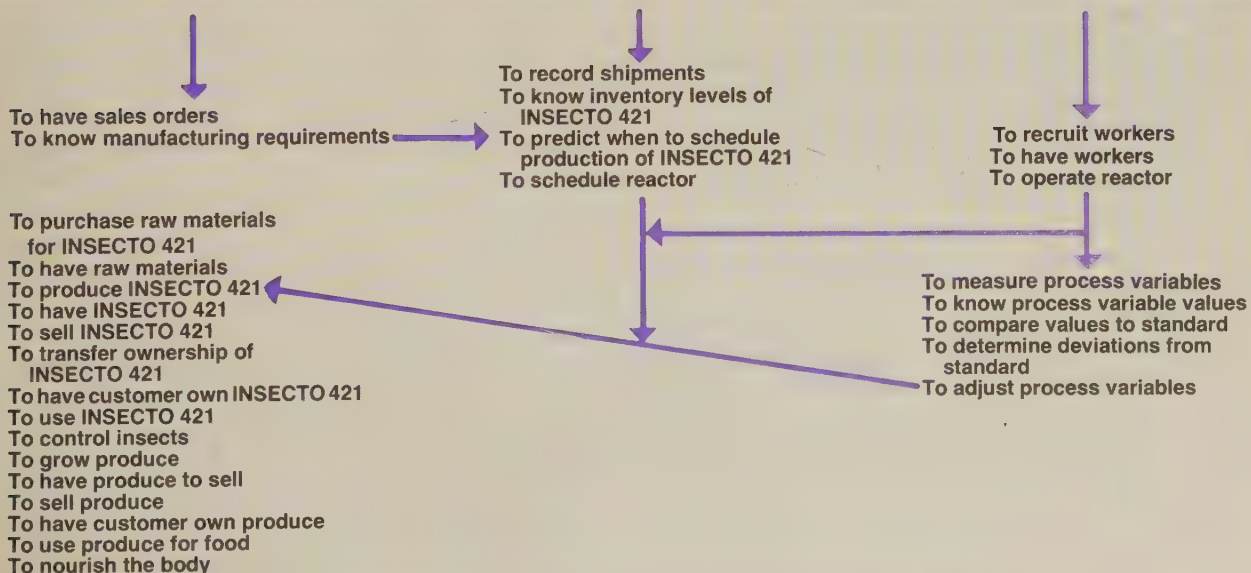
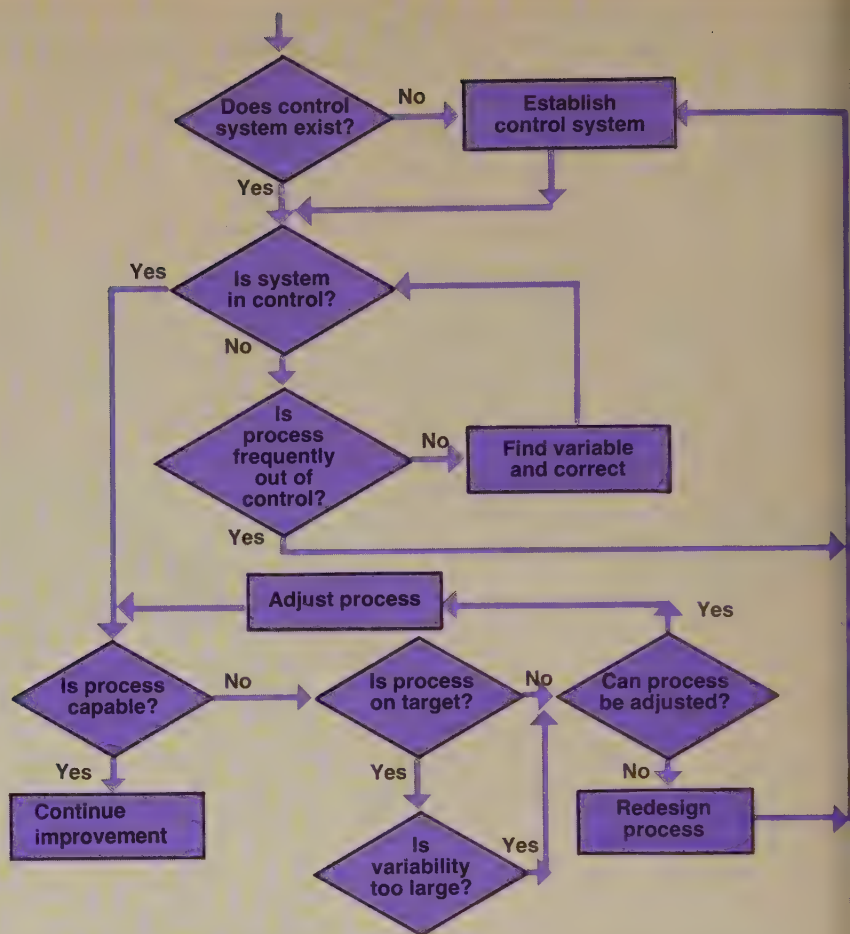


Figure 4. Example of system hierarchy

Figure 5. Flow chart of improvement process



Management should see that projects represent opportunities near the top of the list. The problem solving team should ask:

- Is this an important problem?
- What is the nature of the problem?
- Which system has the problem?
- What is the purpose of the system?
- Is this a design, control, or research problem?

These questions used together with the combined approach should lead the team to the best starting approach for that problem. Once an approach has been chosen, the problem solvers should ask questions that fit the approach. These questions should lead to the desired set of outputs (deliverables) for that step.

Improving products

Products and services must satisfy the customer. Developers of product improvements and new products must know what the customer wants and, if possible, build it into the product. In the design approach, the purpose of the product is well defined before it is envisioned. The system that uses the product will suggest criteria for choosing the final product design. Following the design approach and adapting it to the specific problem should lead to the design of the production system.

Some method of transferring the necessary information from step to step must be available. The deliverables in the design approach are one way to transfer information. Another method is Quality Function Deployment (QFD)

(5-7), which is a tool for recording important points in the development of a new product and process. In practice, QFD looks like a series of extended decision tables. For example, the first table shows how the customer's criteria have been designed into the target solution; a second shows how the target requirements appear in the detail design. Extended to their fullest, QFD tables also show the trade-off among the requirements, competitive position, costs, and test results. As problem solving moves through the design approach, the QFD tables change, with the features of the solution becoming the criteria of the next table. Combining QFD, the deliverables, and the systems matrix will transfer the important necessary information so that problem solvers concentrate on developing a product and process that will meet the customer's needs.

Improving processes

Continual improvement of processes is necessary to improve quality and reduce cost. A process usually should be improved as much as possible before it is replaced with a new system. This improvement will start with the research approach and include the control approach (see Figure 1b). This is the Japanese approach of Kaizen (8).

It is useful to examine a flow chart of the improvement process, which starts by bringing the system into statistical control and then determines the ability of the process to produce quality output (9) (Figure 5). An adequate control system exists only if all the following exist:

- a measure,
- a standard,
- a method for detecting deviations from standard, and
- a counteraction for each known variable in the process.

If the process is frequently out of control, either the control system is not sufficient or several uncontrolled variables affect the process, and the control approach should be used. A one-time deviation is probably caused by a single uncontrolled variable, and the process can be returned to control by locating and controlling the variable.

A process can be incapable because of excess variability or being off target. If the process is not on target, then some variable must be adjusted to move the process to the target. Excessive variability may be an inherent property of the production system or a weakness in the control system. If the capability of the process cannot be decreased by reducing the largest sources of variability or by moving closer to target, the process or some components should be redesigned. This means that the control system also must be redesigned. Eventually, a point will be reached where the system no longer can be improved economically, and it may be necessary to design a new system to achieve the purpose (Figure 1). Such a new system requires a new control system, and so begins again the cycle of process improvement on the new system.

The improvement process also applies to service systems, although it makes less use of the research approach. The number and type of complaints, errors in output, or timeliness of the service measure the system's performance. Data collection and analysis may be necessary to isolate the point at which errors or delays occur so that the design or control approaches can solve the problem.

Conclusions

Management must take the lead in the improvement process. Managers control the resources needed to solve problems and should embrace the philosophy that improvement is essential. They must apply it to their own problems and systems to show their commitment. Each manager in the organization must understand the place of his or her unit in the organization.

In addition, every organization and unit should have a mission statement that contains the purpose and measures of performance. Each organization is made up of systems that turn inputs into outputs, so each system should be identified and its purpose stated.

Customers for each system should be identified to provide them with better output from each system. Customers' problems must be known and the problem-causing situations must be identified. The main customers of management are the employees of the organization.

When reviewing the progress of any problem-solving effort, managers should ask to see the deliverables that

have been generated. This will encourage the use of good problem-solving approaches.

Employees must know how to solve problems. To do so they must be creative and self-disciplined; they must be able to think logically and to work with others; and they need good written and oral communication skills. Knowledge of statistics is essential for the research and control approaches and for management decisions. Don't rely only on employees who already have these skills. Provide the training necessary for others to function at the appropriate level.

Management must ensure that the systems that support continual improvement are developed and used. Among the necessary systems are systems for

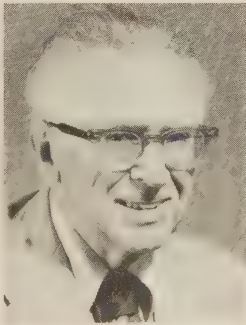
- opportunity finding,
- opportunity rating,
- opportunity selection,
- resources allocation,
- new product design,
- new process design,
- systems improvement,
- people improvement, and
- work environment change.

The environment must encourage people to solve problems. Change the environment by designing a system to change it, and then take the lead to make this change happen. Turn the workers loose and get out of their way. They have the potential to do the job. Let them do it.

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Chemical regulation and

Daniel J. Marsick

Janis M. Adkins

Computers can help you cope with the complicated requirements of today's environmental laws and standards. They can assist with information management and the handling and dissemination of materials. They can track employee exposures, provide training courses, and much more. As you try to meet the requirements of the Hazard Communication Standard and SARA (Superfund Amendments and Reauthorization Act) Title III, the computer can be an invaluable tool.

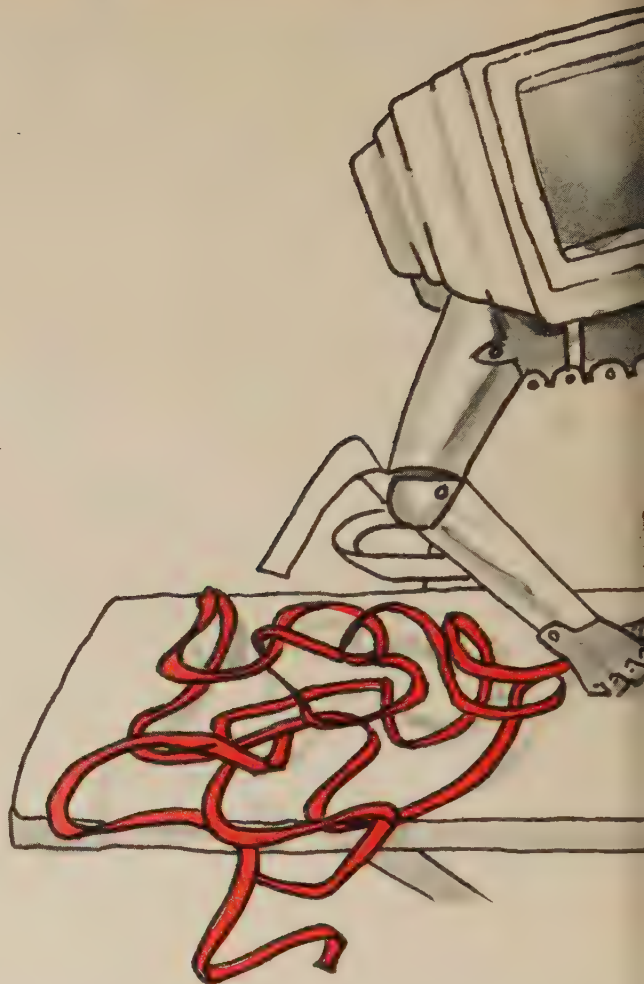
Companies are responding to the diverse requirements of the Hazard Communication Standard and SARA Title III by seeking some or all of these:

- sources of information on hazards in the workplace;
- standardization of material safety data sheets (MSDSs) for easy retrieval and training efficiency;
- integration of sample records, training records, analytical records, and medical records with their MSDSs.

The optimum information management system will aid in chemical inventory and storage recordkeeping; self-training and recording of training efforts; and tracking and recording of chemical distribution by obtaining, interpreting, and distributing the appropriate MSDS. The computer can be used for emergency response, for highlighting safety and health trends, for generating legal reports, and for tracking MSDS distribution. The computer can record chemical inventories; organize, file, and update MSDSs; and track employee medical and exposure histories, as well as training programs. In some businesses, the number of chemicals can be so small as not to warrant any efforts to automate the MSDSs themselves. However, for quick emergency response and for government recordkeeping requirements, some computerized inventory usually is preferred.

In addition to the federal Hazard Communication Standard, many state and local right-to-know laws have dictated conflicting content and format for the MSDS. Automated recordkeeping allows for efficient standardization, fast retrieval, easy update, and low storage requirements. Although systems have been successfully developed by in-house information systems groups, it is almost always less expensive and time consuming to purchase or time-share flexible, commercially available systems. With customization, these systems can work well.

Smaller companies and small health and safety offices can enjoy the benefits of automated systems by using microcomputers and one of the many specialized software packages that handle MSDS and other occupational health information needs. The microcomputer offers the advantages of availability, physical security, and security of access. Just as with larger sized businesses, however, off-the-shelf systems may need to be customized to meet the employer's needs. But because small businesses have fewer



resources with which to hire expensive programmers and systems analysts, they must depend more on the vending company to supply the requisite support.

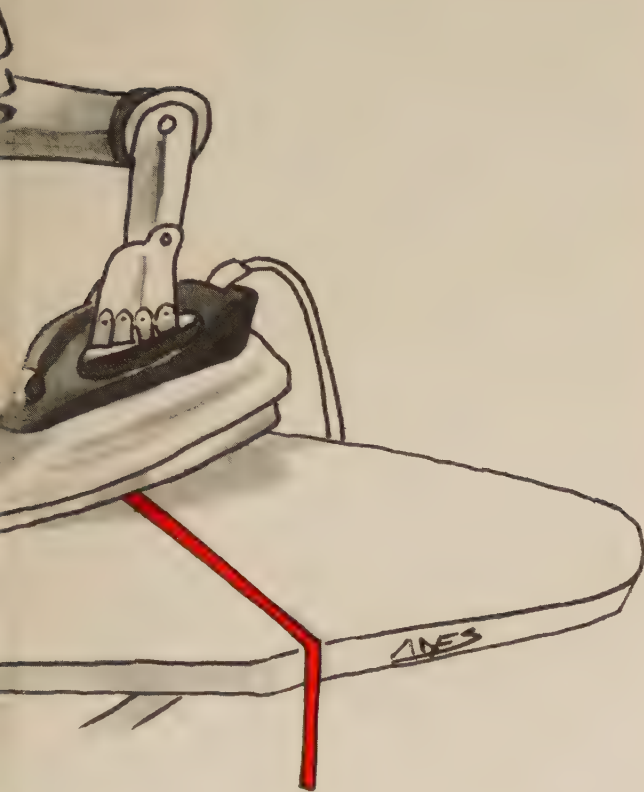
Getting it done

Computerization forces a standardization of reporting and recordkeeping that can be beneficial in the long term but quite upsetting in the short term to the former manual recordkeepers. Initial data entry and software modification also can be quite costly. Do the long-term benefits justify these costs? Only the particular business can answer this question. For most businesses, under today's regulatory climate, the answer would have to be "YES!"

In the case of automating MSDSs, how much of the data entry burden and cost can be diminished by using a supplemental generic MSDS data base? Legally, an employee should have access to the manufacturer's up-to-date MSDS information, whether automated or not. If an employer takes the initiative and updates the MSDSs for chemicals purchased some time ago, the additions or corrections to the manufacturer's data may shift legal liability from the manufacturer to the employer. Therefore, updated MSDS information may have to come directly from the manufacturer.

For many small companies, a fully computerized MSDS system will be hard to afford. Some alternatives can

computer resources



include asking for voluntary donations of time, personnel, and computer support; asking companies to supply their lists or MSDS in electronic form; or funding modules of the entire system over time. For example, the inventory module should immediately be implemented, followed later by a consideration of the cost and benefits of computerizing the MSDS itself.

A company's existing hardware, software, or personnel must be considered when making any decision about computerizing MSDS and health information. Most packages are designed for IBM and IBM-compatible computers, although the cost of hardware is probably not a significant factor compared to the software and personnel costs involved in implementing a new system.

Before purchasing any information management software, you should look for the following standard features:

- index functions and "Help" or menu-driven capability,
- MSDS tracking capabilities,
- sufficient field length to encompass large texts on health hazards or spill precautions,
- enough fields to accommodate optional environmental data that may be required in your state,
- chemical fragment capability,
- ability to search and display select parts of an MSDS, and
- label-making capability.

What you need to do

The *Hazard Communications Standard* (29CFR 1910.1200) requires manufacturers, distributors, users, and importers to provide information to employees on all hazardous chemicals used in the workplace through labels, material safety data sheets (MSDSs), and training programs (1-3).

SARA Title III provides for emergency response planning and notification and for information about chemical substances to be made available to the public.

Section 304 requires immediate notification of the local emergency planning committee and state emergency response commissions if there is a release of certain extremely hazardous substances.

Section 311 calls for any facility that is required to prepare or maintain an MSDS under the Occupational Safety and Health Administration (OSHA) Hazard Communication Standard to submit either copies of their MSDSs or lists of the MSDS chemicals to the state emergency response commission, local emergency planning committee, and local fire department.

Section 312 requires submission of an emergency and hazardous chemical inventory form to the same officials, as either aggregate information about the estimates of average daily and annual quantities, along with the general location of the chemicals or, if requested, the chemical name or common name as it appears on the MSDS, estimates of maximum amounts of the chemical present at any given time, location in the facility, description of storage method, and indication of any trade secret claims.

Section 313 requires certain manufacturing facilities to submit emissions inventories to inform EPA, state officials, and the public about releases of a specific list of toxic chemicals.

Section 322 demands that information be made available to the public upon request, subject to protection of trade secrets.

The index function enables you to search for a specific MSDS or, in some cases, to view a list of all MSDSs. If well structured, this gateway to the MSDS file can lead you to the appropriate MSDS, even if you remember just a few letters of the chemical you are researching. With chemical fragment capability, one can search for classes of chemicals such as all halogenated compounds.

On-line "Help" functions allow the user to get help and instruction while still in the program. They are essential for the novice and occasional user. A menu-driven capability can lead the first-time user through the query maze with little user frustration. Any manual that you receive with the program should be intended for occasional reference and should not have to be used for the initial instruction in program usage.

Make sure the program is easy to use for the intended daily user (e.g., the employee at a work station). Some programs require training just to activate the system. For example, one program requires you to answer multiple questions as to terminal type, disk drive designation for the

data disk, etc. The average worker, often intimidated by a computer, is not likely able to answer these questions readily and may avoid using the computer because of its "complexity." A menu-driven system, although slower, is easier for the average employee to use.

Consider the response time for a query or a print. It took almost 30 seconds for one MSDS to begin to print with one program that we used. Searches, however, usually took 10 seconds or less. In an emergency, every second counts. But before excluding a program, you may want to look at its other features. Emergency response may not be critical in your application. Are there particular modules (such as a mass balance form or remote telecommunication capability) available only from this vendor?

Consider all of your needs for managing hazardous materials so you can expand your system to incorporate other needs, such as training efforts, permit tracking, and emergency response data. If a supplemental MSDS data base is included, what is the frequency of updating and what is the current date of most of the MSDSs? Under the Hazard Communication Standard, new information on a chemical is to be placed on the MSDS within 90 days of availability. Likewise, for emergency purposes under Title III, one must have the most up-to-date information. A data base that is not updated regularly could put you in violation of the law, as could outdated MSDSs. These commercially available supplemental data bases can overlap, may give sufficient information for your area of interest, and may be of widely varying formats. For some users the ability to output SARA Title III Tier I and Tier II forms may be a significant factor in their decision to buy a particular data base.

Since the typical microcomputer is used for more than cataloging MSDSs, you should be able to retrieve the MSDS program easily and quickly when necessary without tying up the entire resources of the microcomputer. Some early programs literally required a dedicated microcomputer and a computer-competent operator. Some functions of even more recent programs require a fair amount of computer expertise. An extra investment in a large hard disk, expanded memory, or a new operating system may be required before some microcomputers can run some of the commercial MSDS programs.

In addition to obtaining and interpreting the MSDS, the program should be capable of tracking the distribution of the MSDS, including distribution to other companies, employees, and community groups. Such a record could prove invaluable in supporting employers' past actions in contested cases of product or employee liability.

The post-purchase support should be a key factor in deciding which off-the-shelf microcomputer program should be purchased. Does the vendor understand your information and computing needs for MSDSs? Does he or she have the resources to modify the off-the-shelf program

The sources

Extensive lists of resources are available directly from Dan Marsick. These include lists of:

- software vendors with complete Generic MSDS data bases,
- commercially available MSDS software for microcomputers,
- occupational health and safety information systems for mainframes and minicomputers that include MSDS modules,
- commercial newsletters,
- publicly available online data base sources,
- right-to-know training resources and consultants, and even
- automated chemical lists for hazard determination.

to your specifications? Can you communicate effectively with the vendor's representatives? Can the vendor answer on-the-spot questions about the program when you run into trouble? Is he or she willing to provide source code and full documentation to let you modify the program yourself?

Other features to look for

The available programs vary significantly, and your needs must be considered when choosing any software package. Some packages have additions or add-ons that you might not have thought about:

- User groups, often coordinated through the vendor, can be invaluable in fully utilizing the capability of any of these microcomputer programs.
- Some software will allow you to store, retrieve, and track an MSDS from the supplier to the employee.
- In some implementations, you use your own data base manager to manipulate data. Use of a data base manager is advantageous for linking other files with an MSDS module and customizing off-the-shelf programs.
- One software package provides access to information needed when responding to emergency incidents and maintains an audit trail of key compliance events including manifests and training. It offers fast retrieval of information for MSDSs and can document right-to-know compliance.
- Assistance in manufacturer MSDS entry and labelmaker programs is available.
- The new CD-ROM technology allows access to large data bases.
- Some programs record substances and locations but allow you to maintain manual files of MSDSs. For many firms using a small number of chemicals or mixtures, it may be more cost effective to maintain an automated inventory but a manual MSDS file, considering the personnel and computer costs involved in inputting the MSDS information.

How will my staff learn all they need to know?

Computer-based training (CBT) can help quickly train people in workplace hazards and right-to-know compliance. For the worker, advantages of interactive CBT include individualized training, flexibility in scheduling, and the ability to customize. In contrast to lectures, CBT can give a uniform presentation and avoid

multiple interpretations of the subject matter.

The learning environment is tailored to each employee. Extensive software branching automatically adapts the level of difficulty to the employee's knowledge level and learning aptitude. On-the-spot decision making and interest are developed through simulation, text, and sound. Peer pressure, fear of failure, embarrassment in classroom situations, and other barriers to effective learning are minimized, creating a better climate for questions and learning.

CBT provides baseline information and eliminates administrative tasks such as test scoring for the trainers. Documentation of any and all training is immediately available to management. By supplying individualized training, less time is lost from the job compared to traditional group classes.

Is CBT right for you?

Implementation costs can include the costs of software and hardware. Off-the-shelf software is usually more cost effective than in-house efforts. Software costs, however, pale against the costs of hardware, possibly including stand-alone microcomputers, video monitors, and videodisc players. The lack of group reinforcement and social interaction can be a deterrent to CBT. The appeal of conferences and training sessions often lies in the ability to meet and socialize with one's peers. Questions, ideas, and information are exchanged freely, sometimes resulting in improved efficiency. For many individuals, especially older persons, the computer is perceived as a complex machine at best, and a threat to their security at worst.

Choosing the right interactive CBT to buy requires that you consider customization, reading level, modularity, question randomization, ease of use, trainee interest, and performance. CBT should be customized to meet the individual needs of the industry or facility. Performance is often difficult to measure, but both the speed of training and knowledge retention by the trainee should be carefully measured. A pre-test and a post-test are helpful in this regard. Ease of use and trainee interest will increase the performance of any training program, but the ability or inability to use a computer should not bear upon the usage of the CBT. Games, graphics, sound, color, and simulations can make any CBT more interesting.

Most training programs that use personal computers can be categorized into those that test comprehension of a manual or training film through questions and games and those that present lifelike simulations. Simulations test the application of the learned material and through interaction can test the decision making capability of the trainee.

Taking the concept of "drill and practice" a little farther, one vendor uses a "Jeopardy" game show format. The course consists of a pre-test, three regular rounds,

three challenge rounds, six supporting graphics, six supporting tutorials, and a post-test. Generally, the gamelike format of these programs appeals to people and, if the content is relevant to the workplace, these can be useful.

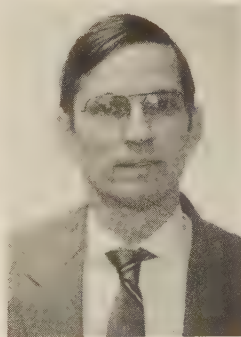
Caveat emptor

Many factors enter into the selection process for MSDS collections, software, and training packages. Each available product must be judged by how well it meets your needs. A program that matches your needs or that can be customized to meet your needs is the most important criterion for selection of any off-the-shelf commercial product. Let the buyer beware in this rapidly growing, competitive, and unregulated marketplace. For more information on a particular program or product, contact users and user groups for their experiences with both the program and vendor support.

All comments and opinions expressed herein are those of the authors and do not reflect any official OSHA policy or procedure.

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Daniel Marsick is an Industrial Hygienist and MSDS specialist in the Technical Support Directorate of OSHA (200 Constitution Ave., N.W., Washington, DC 20210; 202-523-7066). During the past few years, Marsick has been compiling a list of available resources for dealing with hazard communication requirements, and he has been a discussion leader on hazard communication at national ACS meetings. Marsick received his Ph.D. from American University and is CHEMTECH Advisory Board representative from the Division of Chemical Health and Safety.



Janis M. Adkins has been a regulatory consultant, trainer, and author since 1976. Her 1988 textbook, *Formula for Safety: Making Communities Safer from Chemical Hazards*, was one of the first community-oriented explanations of SARA Title III. She has been involved with a number of newsletters in the field as well. Adkins has a B.S. in environmental studies from the State University of New York, Empire State College.

Heart Cut

(continued from p. 7)

Although cryogenic separation of O₂ and N₂ has been exquisitely optimized, it still involves thermodynamically **costly phase changes**. K. A. Lundy and I. Cabasso (*Ind. Eng. Chem. Res.* 1989, 28[6], 742) successfully separated O₂ and N₂ by using multilayer composite membranes (e.g., poly[amino]siloxanes, polysulfone, and poly[2,6-dimethyl]-1,4-phenylene oxide) in various layered combinations. (CMH)

Do thin stockings really keep your legs warm? The warmth may be more apparent than real. Questions pertaining to **advances in protective clothing** are discussed in the July 1988 issue of *Ergonomics*. (KFS)

Don't send those plating baths to the waste-disposal facility yet—the metals may be recoverable. P. B. Lloyd, S. Ganesan, and P. K. Lim (*Ind. Eng. Chem. Res.* 1989, 28[5], 557) recovered dissolved and suspended metals at oil–water interfaces, with many recovery rates in the 90+ % range. In most cases a “collector,” or **surface-complexing agent**, was needed to achieve separation, but some occurred spontaneously. For example, copper(II) recovery with kerosene–water and no collector was 92 %. (CMH)

When styrene (b.p. 145 °C) is made commercially by dehydrogenation of ethylbenzene (b.p. 136 °C) one gets a tough-to-separate equilibrium mixture. Distillation is difficult and, since the goody comes off last, costly. Separation of olefins from saturated hydrocarbons has been achieved with facilitated transport membranes. This method depends on the selectivity of a **carrier–permeate complexation** reaction and the relative solubilities of the permeates in the membrane phase. C. Koval, T. Spontarelli, and R. Noble (*Ind. Eng. Chem. Res.* 1989, 28[7], 1020) have looked for the conditions under which ionomer membranes will lead to maximum separation. They used nalion membranes varying in thickness from 30 to 200 μm, two different membrane solvents (water or 50 % ethanol), feedstream concentrations of 0.1–1.0 mol L⁻¹, and two different cations, Na⁺ and Ag⁺. The choice of cation was based on the fact that Ag⁺ forms complexes with olefins. Separation factors (styrene permeability/ethylbenzene permeability) were 5 to 18 times as great with the Ag⁺ as with the Na⁺ membranes. (DLN)

Concern with blood cholesterol levels has made everybody aware of mono- and polyunsaturated fatty acids and esters. If the work of D. Neibecker, J. Poirier, and I. Tkatchenko (*J. Org. Chem.* 1989, 54, 2459) were to become commercial, polyunsaturated fatty esters will be easy to make. The secret is to use the telomerization of **1,3-butadiene in methanol** to form a mixture of 1-methoxyhexadecatetraene and 3-methoxyhexadeca-1,6-10,15-tetraene. A mixture of the two is then carbonylated by using CO and palladium catalyst to

give a single ester—methyl heptadeca-3,7,11,16-tetraenoate—in 50 % yield. To prove the structure, the researchers hydrogenated this ester to methyl margarate. This fascinating method for synthesizing fatty esters doesn't depend on vegetable or animal sources. (BST)

A variety of electrophilic catalysts with chiral ligands have been used for the Diels–Alder reaction. Particularly promising are the borates produced by the reaction of borane–THF and tartaric acid. The discovery and application to the reaction between substituted acrylic acids and conjugated dienes was described by H. Yamamoto et al. (*J. Am. Chem. Soc.* 1988, 110, 6254). Now further details are given of the catalyst and its application to the corresponding **reaction of substituted acroleins**, which occurs with up to 97 % enantiomeric excess (*J. Org. Chem.* 1989, 54, 1481). (AJC)

Cross coupling of halides catalyzed by palladium is now as widely employed as the original symmetrical Heck reaction. An example is the synthesis of stilbenes from β-bromostyrenes and aryl Grignards. A recent study of this reaction has not only clarified the mechanism but also given enough insight into catalytic optimization to allow **platinum catalysis** (Brown, J. M. et al. *Chem. Commun.* 1989, 458):



For platinum, each of the postulated catalytic intermediates is observable with a finite lifetime under the reaction conditions, contrary to the common experience that catalysis normally proceeds through transient intermediates inaccessible by direct observation. This slow catalysis by platinum can be increased in rate by a factor of 10⁻³ through intervention of electron-transfer catalysts. (AJC)

(continued on p. 64)



"Their grievance committee is here to see you."

We made it!

There seemed to be plenty of oil, but G. M. had just begun designing a no-lead engine. Willie Sutton was free, but Lt. William Calley was being tried for his role in the Mylai massacre. The Kent State killings were still months away, but the excitement of the first Earth Day lingered. Cyclamates had been banned, but nobody yet cared about dioxin or radon or EDB, much less Alar. People were reading *The Godfather*, *Portnoy's Complaint*, and Rene Dubos' *So Human an Animal*. Nasser had named Sadat Vice President of Egypt. Khadafy had named himself Premier of Libya. The Shah resigned. Israel bombed Cairo, and a 747 flew to Europe for the first time. The U.N. refused again to seat Peking, and the New York Mets won their first World Series. President Nixon ordered our stocks of germ warfare agents destroyed and initiated a military draft. At the White House, Eugene Ormandy accepted the Medal of Freedom, and John Lennon returned his Order of the British Empire medal to the Queen to protest Britain's role in Vietnam. It was 1970, the end of The Sixties. Bertrand Russell had just died, and CHEMTECH was about to be born.

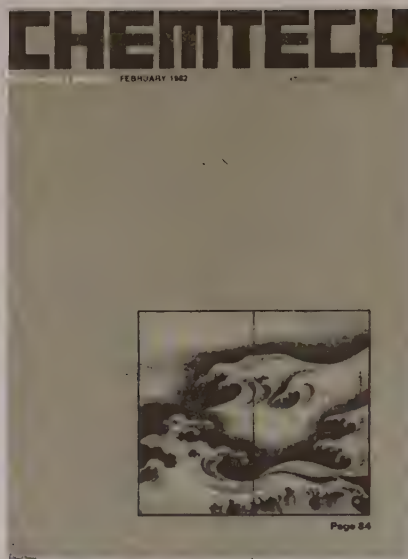
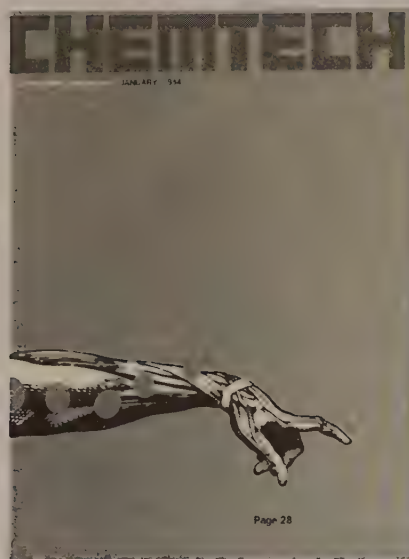
Yup, boys and girls, we are coming up on CHEMTECH's twentieth anniversary. There's a whole CHEMTECH generation out there. A couple of anecdotes brought that home to me. One chap told me that he thought CHEMTECH had changed a lot since his grad school days when he read every article. Lately he finds himself reading Heart Cut ("That's still good") but only two or three of the features. "The magazine's changed a lot, you see," he told me. I thanked him for his insight and asked what he was doing now. "Oh, I'm managing three groups now, a lot of planning and meetings, not much chemistry." I then asked about the two or three articles he reads. "Well, let's see . . ." he began, and then his face lit up. "Maybe I've changed."

One of our authors said, "You know, I started reading CHEMTECH with volume one at Temple, while I was finishing up my Ph.D. and trying to start our company at the same time." He talked about reading CHEMTECH while learning how to be a CEO, winning our Leo Friend Award (1) during his major expansion, and getting acquired twice. He concluded, "You see, I'm the CHEMTECH generation!"

Is it any wonder, with stories like these piled up, that we feel celebratory as we open Vol. 20? One of the special things we're going to do in this volume is visit each month an area we explored earlier to learn how it has progressed. The two papers that immediately follow are representative of what's to come.

We realized how much can be learned from such retrospectives back in 1976 when each month we reprinted a landmark paper from what started as *The Journal of Industrial and Engineering Chemistry*. It





went back a lot further than 20 years, of course—all the way to the discovery of Baekelite, which Leo Baekeland described in the inaugural volume. But one of the more startling things we learned in that earlier retrospective could well portend what's about to come. In 1961 Harris wrote a now classic piece (2) on project evaluation. He created a checklist of important parameters that was truly comprehensive . . . for 1961. But when we asked him to update his list in 1976, we learned that a lot had happened in 15 years. Concern with the environment, *wholly absent from the original checklist*, had assumed its current importance.

So join us as we ask, "What's new?" In fact, if there's an area we covered in the past that you'd like to see updated, tell us. Use the phone numbers and addresses in the masthead on page 2. You'll also find CHEMTECH board members listed there. They are selected by our 22 Mentor Divisions (3), which will be especially active in our celebrations. If you want to help shape those divisional activities, contact your divisional board members and tell them. Or tell us. Remember, CHEMTECH is your magazine.

BSK

Notes

- (1) As is the case each March, the 1989 Leo Friend Award for the CHEMTECH paper that most promotes the advancement of chemical technology will be announced in the March 1990 issue.
- (2) Harris, J. S. *Chem Eng. News* April 17, 1961, p. 110.
- (3) In the beginning, the ACS Board told the I&EC Division that a magazine couldn't be launched for a single Division. The Division then asked 11 other Divisions to send representatives to a meeting to discuss a new magazine on "applied chemistry." That group resolved that there should be such a magazine, and that they, reporting to the ACS Board, should be responsible for oversight of its performance, both intellectual and financial. The ACS Board bought it. Those pioneer Divisions knew what we were up to. Not everybody else did. But since that time, 10 other Divisions have been granted their request to have seats on that Board. These are CHEMTECH's Mentor Divisions.



The prospects for biodegradable plastics

F. Rodriguez

Although they represent a small fraction of total packaging materials waste, plastics are a visible, much-criticized target. The expanding replacement of metal and glass by plastics is likely to increase public concern. In his message to Congress last year (1) President Nixon set two major Solid Waste Management goals for the immediate future, "(a) making products more easily disposable—especially containers; and (b) re-using and recycling a greater proportion of waste materials." A specific directive called for "development and use of packaging and other materials which will degrade after use—that is, which will become temporary rather than permanent wastes."

There certainly is no great challenge in making an unstable polymer. Ordinary polypropylene film that has not been properly stabilized is reduced to flakes in a few weeks. Ultraviolet light is a potent degrading agent. Kodak patented a copolymer of ethylene and carbon monoxide that degrades in sunlight (2). Guillet (3) and Scott (4) have pursued the idea of sunlight-degradable polyolefins. However, sunlight and air are rather pervasive agents that we should have economic difficulty in keeping away from stored products.

A more drastic change in environment occurs when a packaging material is buried in a sanitary landfill. The moist, warm, bacteria- and fungi-laden surroundings should offer a contrast to normal storage conditions. On the other hand, the literature leads one to conclude that all synthetic polymers are resistant to microbiological attack, and that only in the case of plasticized films is there any growth observed. However, one must remember

that the paramount feature sought by polymer engineers and chemists has been stability. Biodegradability has not been an attraction. Few workers have designed their experiments by a technique of steepest descent, so to speak, to the depths of degradation. But now the picture has changed, and we must re-examine the evidence in quest of the selectively degradable polymer.

Naturally occurring high polymers

With natural rubber, *cis*-1,4-polyisoprene, the question of biodegradability is clouded by a host of factors, as is the case with most synthetic rubbers. The highly unsaturated polymer is, by itself, quite susceptible to oxidative degradation. Ultraviolet light and ozone accelerate the deterioration. Most tests have been carried out on compounded samples that usually contain sulfur, sulfur compounds, zinc oxide, waxes, and fillers such as carbon black or silica, some of which are nutrients for certain microorganisms. Paraffin wax and elemental sulfur fall in this category. Others, such as zinc compounds and some organic sulfur accelerators are biocides of a rather general nature. Most workers agree that microbiological attack of *compounded* rubber is less significant than attack by atmospheric oxygen (5-9).

Raw latex is susceptible to bacterial attack. In the tropics where it is grown, bacterial populations in the soil may exceed 10^9 organism/g. The major result is coagulation owing to bacterial attack on the emulsifying system. However, even in dried, coagulated rubber, fungi, bacteria, and yeasts can grow readily when rubber is stored at high humidities. Thin strips of latex are completely decomposed in three to four weeks when buried in soil. The attacking organism is a species of *Streptomyces* (10).

However, it is possible to separate biological effects from chemical degradation. In 1936, Spence and Van Niel carried out a convincing demonstration of the biodegradability of the pure polymer by optimizing conditions (11). A high-moisture, high-surface area situation was induced by using purified, sterilized, natural rubber latex, which had been diluted to about two percent hydrocarbon solids. Initial test compared the behavior of sterile latex to latex containing a trace of garden soil. After 28 days of incubation at 30°C, the sterile latex was almost indistinguishable from fresh latex in terms of recoverable rubber, and in the intrinsic viscosity of that rubber. The soil-inoculated latex contained 20 percent less rubber hydrocarbon. Also, the molecular weight of the remaining



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rubber had decreased so that solution viscosity was hardly distinguishable from that of the solvent. By repeated platings on an agar-latex medium pure cultures of four strains of *Actinomyces* were prepared. All four were effective in reducing the amount of rubber present (Table 1). The stability of the sterile controls indicate that ordinary oxidation was not a factor.

Cellulose has received more attention than any other polymer since it is attacked by a wide variety of microorganisms, and since it is often used in textiles without additives to complicate the interpretation of results. Cellulose represents an appreciable fraction of the waste products that make up sewage and garbage. It is fortunate that it does decompose readily. According to one source, 96 percent of the cellulose in sewage can be decomposed in a few weeks (12). Fermentation of cellulose has been suggested as a source of chemicals such as ethanol and acetic acid, but it has not achieved any commercial importance (12).

In examining the work on cellulose degradation, it is of special interest to note the adaptability of organisms to attack derivatives since some, such as the acetate and nitrate, have long been used as films and coatings. Wirick (13, 14) has examined the degradation of substituted cellulose by a specific enzyme derived from the mold *Aspergillus niger*. As have many workers in this area, he chose to study the water-soluble derivatives. These included sodium carboxymethyl cellulose (CMC), hydroxyethyl cellulose, methyl cellulose, and hydroxypropylcellulose. Wirick found that the important correlating parameter is the number of completely unsubstituted anhydroglucose (AHG) units remaining in the polymer. The AHG unit has three hydroxyl groups so that one often speaks of the average degree of substitution. In plastics, the triacetate is fully substituted. The diacetate is made by hydrolysis of the triacetate so that, although the average degree of substitution that results is two, there probably are no unsubstituted AHG units. The water-soluble polymers studied by Wirick are made by limited reaction of the hydroxyl groups. Wirick was able to characterize these by completely hydrolyzing the samples chemically and analyzing for the free, unsubstituted glucose. By using statistical assumptions that seemed reasonable, he estimated the concentrations for these polymers of singlets (unsubstituted AHG units whose neighbors both are substituted), doublets (adjacent pairs of unsubstituted AHG units), and triplets.

The conclusion, reinforced by previous work, is that CMC degrades only where there is a sequence of at least three unsubstituted AHG units. The nonionic cellulose ethers all seem to be attacked to some extent even at isolated, unsubstituted AHG units. Although cellulase can be regarded as a cellulose-solubilizing enzyme, Selby (15) has shown that typical cellulases can be separated into component enzymes that are quite different in activity.

Most tests indicate that cellulose acetate is quite resistant to degradation, except when plasticized. On the other hand, Snoke concluded that cellulose acetate fiber that had been submerged in seawater had been attacked severely by bacteria (16).

Table 1. Degradation of dilute natural rubber latex by four strains of actinomyces (11)

Sample conditions	% Rubber recovered
Coagulated at once	100 (Control)
Coagulated after 28 days at 30°C	
(a) Sterilized sample	100
(b) Inoculated, strain 1	30
(c) Inoculated, strain 2	64
(d) Inoculated, strain 3	44
(e) Inoculated, strain 4	49

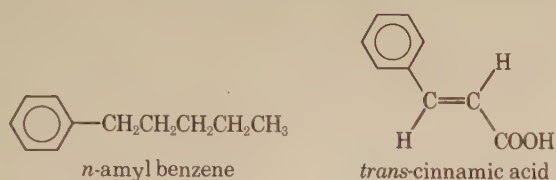
Aspergillus niger is a popular test organism, and is included in the ASTM standard procedure (17, 18). Wirick's work would seem to indicate that one of the reasons for the fungus-resistant nature of unplasticized cellulose acetate is the lack of unsubstituted AHG units. Another plastic derived from cellulose is ethyl cellulose. The more popular grades of this ether have a high degree of substitution, around 2.5. Once again, this would lead to a low concentration of unsubstituted AHG units. While its flammability rules it out as a contender in most applications, it is of interest that cellulose nitrate is considered biodegradable. Growth of microorganisms was a problem half a century ago in explosives plants (19). Whether or not enzymes attack the nitrate at unsubstituted AHG units or whether the mode of attack is different does not seem to have been elucidated. The presence of nitrate groups does provide a nutrient for many organisms.

Carbon-chain polymers

Most reviewers agree that synthetic polymers are resistant to bacterial or fungal attack (5-8, 20-25). Damage that does occur often can be traced to a low molecular weight component such as textile sizing, lubricant, stabilizer, or plasticizer. The damage may consist of staining by migration of a pigment generated by a microorganism into the polymer (26, 27). Since most poly(vinyl chloride) is plasticized, the microbial susceptibility of plasticizers has received a great deal of attention (28-32).

The least expensive, most popular thermoplastic materials are characterized by having polymer chains exclusively composed of carbon atoms. It can be argued that although natural rubber has an all-carbon backbone, it is highly unsaturated and it is a naturally occurring polymer; consequently, it is more susceptible to microbiological attack than the synthetic materials. In recent years a great deal has been learned about microbial oxidation of hydrocarbons. Once thought to be a rather rare phenomenon, it is now understood as relatively common though often masked by simultaneous processes. In a recent review (33) it was pointed out that many organisms metabolize alkanes in the C₁₂-C₄₀ range by conversion of the end carbons to carboxyl groups. Aromatic compounds also are oxidized by numerous species. Organisms that will catalyze specific chemical changes in hydrocarbon molecules have been investigated. Microbial conversion

of *m*-xylene to *m*-toluic acid (34, 35), and conversion of *n*-amyl benzene to *trans*-cinnamic acid (36) are examples.



For some time it has been known that jet fuels are susceptible to microbial attack. The idea of converting the fuel to a stable emulsion accelerated interest in this system because water and a high surface area of hydrocarbon would be available, giving ideal conditions for growth. The emulsions are useful because they increase the low-shear viscosity of the fuel and decrease burning rate in case of a spill. The high-shear viscosity of the highly non-Newtonian emulsions is low, so that injection into engines is not impaired. Both bacteria and fungi were found to grow at the fuel-water interface (37). Hedrick et al. (38) reviewed the past work on identification of species, and also added a number of new species. Bacteria, actinomyces, molds, and yeast all grew well in water-fuel mixtures. Some survived in fuel alone over periods of four to six weeks, but did not grow.

Aside from demonstrating the ability of many microorganisms to utilize hydrocarbons, the work on jet fuel has also led to studies of biodegradability of polymers used as tank liners, baffles, and hoses. These studies are discussed below. At least one attempt has been made to extend the biodegradation of paraffins to polymer molecules. Jen-Hao and Schwartz (39) studied the bacterial attack on a series of polyethylenes by a species that grew well on paraffin (wax?). The bacterial count was found to increase for about a week for molecular weights up to 17,000. Then it dropped slowly toward the level found in carbon-free substrate. Experiments disclosed that only the lowest molecular weight polymer was attacked when fresh nutrient solution was added to a "used" polymer from previous bacterial attack. The conclusion was reached that low molecular weight fractions were being metabolized, and that once they were extracted from the polymer, the higher molecular weight materials were no longer susceptible. Unfortunately, the hypothesis could not be substantiated by a technique that measured molecular weight distributions.

The resistance of high molecular weight material is understandable if the attack mechanism is oxidation at the ends of molecules. Presumably chain ends buried inside crystallites would be inaccessible. Polyethylene above a molecular weight of several thousand crystallizes in a folded chain in which chain ends are unlikely to be found near the surface. Low molecular weight materials crystallize as extended chain crystals with surfaces made up of chain ends.

One specific application of hydrocarbon metabolism is in the area of single-cell protein production. Both bacteria and yeasts grow on hydrocarbons when mineral nitrogen is added to the medium (40-42). The cell mass produced is high in protein and can be harvested by separa-

tion from unchanged hydrocarbons. The major potential for such protein is for feed and food uses. However, the process has been used where the primary goal is to dewax crude oil fractions. The alkanes in the range of C_{18} - C_{24} are degraded with a consequent lowering of the pour point of the oil (40). Despite the large volume of work on the subject, there appears to have been no incentive to work with paraffins of very high molecular weight, i.e., in the polyethylene range. It certainly can be concluded that there is no shortage of microorganisms that attack hydrocarbons. A similar phenomenon is the microbial degradation of ozocerite (a waxy hydrocarbon) by yeasts in ozocerite-bearing soils (43). The hydrocarbon is converted to resinous materials and microbial cells.

When considering carbon-chain polymers other than polyethylene or natural rubber, the literature holds little evidence that microbial attack can be induced. It must be pointed out again that most workers have not generally sought conditions and organisms that would induce attack. Instead, the tests have been of existing materials under conditions of above-ground, moist, tropical climates. The most common test is challenge by a relatively small group of molds. However, some workers have aged samples in soil or in other wide-spectrum natural communities of microorganisms. ZoBell and Beckwith (44) concluded that rubber products are attacked by microorganisms that had been isolated from seawater. Styrene-butadiene, acrylonitrile-butadiene, and chloroprene rubbers were attacked (oxygen consumption) over a period of 10 days. Snoke (46) also found these rubbers to be susceptible. Since the samples used were compounded with sulfur, fillers, and the like, it is not clear that the polymer was the exclusive source of carbon being used in these tests. Zyska (45) reported that rubber in mining cables lost tensile strength and decreased several decades in volume resistivity when buried in soil. A nitrile rubber coating was found to deteriorate when exposed to a bacterium and a fungus over a period of a few weeks (46). Whether or not the latter sample was compounded with plasticizer is not reported. Work by Leeftang would indicate that the pure, uncompounded rubber polymers are not attacked except for natural rubber (8, 47).

Heterochain polymers

The primary step in metabolism of paraffin polymers appears to be oxidation. One might hope that chains containing hydrolyzable groups could be attacked in the chain in random fashion to reduce molecular weight more efficiently than in oxidation of chain ends. It has been found in proteolytic (protein-hydrolyzing) enzymes that some, termed "endopeptidases," can attack only bonds some distance away from terminal carboxyl or amino groups, whereas others, termed "exopeptidases," require an adjacent terminal group (48). The latter enzymes then remove amino acid groups one at a time from the ends of proteins. Also, these enzymes may be specific for a given amino acid. While specificity is desirable in analytical procedures, it is not desirable in intentional biodegradation. Therefore, it is worth noting that esterases (ester-hydrolyzing enzymes) include members that are

not specific, although the rate at which esters are hydrolyzed varies with structure (49).

Because of the interest in biodegradability of plasticizers, a number of polyesters with molecular weights up to several thousand have been studied. Invariably some growth of fungi has been noted. Berk et al. (31) challenged a total of 127 plasticizers with 24 species of fungi, which included the 6 organisms recommended by ASTM (17). Most of the plasticizers were dispersed in a mineral salts agar medium, inoculated with a spore suspension and incubated 2 weeks at 29°C. Five polyesters showed superior ability to support growth as shown by the diameter of the colony of spores after 2 weeks (Table 2). It can be seen that lower molecular weight esters and acids did not support as luxuriant a growth. Nine polyesters presumably were based on adipic (C₆H₁₀O₄) and sebacic (C₁₀H₁₈O₄) acids. As a class, the polyesters were exceeded only by ricinoleates in ability to support growth. More recently, Darby and Kaplan (50) examined the ability of diols, polyesters, and urethanes to support growth of the six ASTM fungi. Polyurethanes will be discussed below, but it should be mentioned here that these polyesters were found to support "heavy growth" in a matter of a few weeks.

Booth and Robb (29) buried specimens of poly(vinyl

Table 2. Polyesters challenged by 24 species of fungi (31)

Compound	Average growth (Colony diameter, cm)
Sebacic acid polyester	6.8
Polypropylene sebacate	5.9
Sebacic acid polyester	5.1
Polyester	5.6
Polyester	6.0
Dibutyl sebacate	4.4
Diethyl sebacate	2.9
Sebacic acid	4.8
n-Butyl sebacate	2.6

Table 3. Clearing of butylene glycol polyadipate with various nutrients (28)

Nutrient	Organism											
	26C		20C		2C		16C		10C		1C	
	G ^a	C ^b	G	C	G	C	G	C	G	C	G	C
None	—	—	—	—	—	—	—	—	—	—	—	—
Glucose, 1%	+	+	—	—	—	—	—	—	—	—	+	—
Glucose, 2%	+	+	—	—	—	—	—	—	+	—	+	—
Peptone, 0.5%	+	+	+	+	+	+	+	+	+	—	+	—
Peptone, 1.0%	+	+	+	+	+	+	+	+	+	+	+	+
Peptone, 2.0%	+	+	+	+	+	+	+	+	+	+	+	+
Casein hydrolysate, 0.5%	+	+	+	—	+	+	+	+	+	—	+	+
Casein hydrolysate, 1.0%	+	+	+	+	+	+	+	+	+	+	+	+
Casein hydrolysate, 2.0%	+	+	+	+	+	+	+	+	+	+	+	+
Yeast extract, 0.05%	+	—	—	—	+	—	+	—	—	—	—	—
Yeast extract, 0.5%	+	+	+	+	+	+	+	+	+	+	+	+
Yeast extract, 1.0%	+	+	+	+	+	+	+	—	+	+	+	+

^a G = growth
^b C = clearing

chloride) plasticized with various compounds in soil that was enriched by two species of bacteria. Polypropylene adipate and sebacate both were attacked readily as evidenced by weight loss. Of 13 plasticizers tested with a barium-cadmium stabilizer, only the di-isooctyl esters of adipic, sebacic, and azelaic (C₉H₁₆O₄) acids exceeded the rate of degradation of the polyesters. Weight loss after 8 weeks averaged 8.5% for the isooctyl esters, 4.3% for the polyesters, and less than 2% for the other plasticizers. This would indicate that bacteria attack polyesters with the same eagerness as do fungi.

Klausmeier (28) used a different technique to look at the biodegradability of esters. Butylene glycol polyadipate, (not characterized as to molecular weight but probably in the range of mol wt = 2000) was among those tested. The plasticizer was dispersed in a medium containing agar and a yeast extract. For isolating fungi, penicillin and streptomycin were added to suppress bacterial growth. Using various plasticizers, 189 bacteria were isolated from 79 soil samples. Growth of microorganisms that might occur by using yeast as nutrient could be distinguished from hydrolysis of the esters because hydrolysis led to clearing of the emulsion. From 127 soils, 274 fungi were isolated also.

An important feature of Klausmeier's work was the distinction between organisms that would grow with a given plasticizer as the sole source of carbon, and those that would grow only in the presence of some added nutrient. The whole picture resembles the cooxidation phenomenon, and is a broader instance of cometabolism. Butylene glycol polyadipate was found to be quite susceptible to attack by fungi. Of 51 fungal isolates utilized, only one was adventitious—that is, required a yeast supplement to degrade the polyester. On the other hand, when 9 bacterial cultures were tested, only 3 grew and all 3 required a supplement. The importance of the type and quantity of nutrient is brought out in Table 3 where 6 nonfilamentous organisms (presumably bacteria) that did not utilize the polyester were tested with 4 nutrients. Clearing indicates hydrolysis of the polyester. Growth of the organism is not always accompanied by clearing. In some cases an optimum concentration of nutrient seems necessary. For example, a yeast extract concentration of 0.5% gives clearing with organism 16C, but higher or lower concentrations do not.

Polyurethanes, especially the foams based on polyether and polyester diols, have been studied in microbiological systems for some time. Hydrolytic instability may be evidenced on immersion in hot water. Ossefort and Testroet (51) examined millable elastomers based on polyesters and diisocyanates. Deterioration by fungi was noted at high humidities near room temperature.

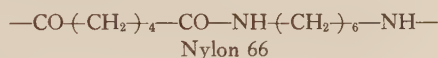
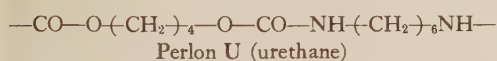
At about the same time, other workers (52) had found that a polyether-based urethane gum was more resistant to attack by *Aspergillus niger* than polyester-based gum. When the gums were cross-linked by sulfur they all were more resistant. Cross-linking by peroxide did not make them resistant. In one test a compound consisted of: polyester-based urethane, 100 parts by weight; carbon black, 30 parts; dicumyl peroxide (40%), 3 parts. Slabs

were cross-linked under pressure for 30 min at 310°F. A sample of this material placed on nutrient medium and inoculated with *Aspergillus niger* showed "profuse" overgrowth after only one week.

It was mentioned in the section on hydrocarbon oxidation that jet fuels have been found to be subject to microbial attack. Crum et al. (46) coated aluminum rods with polymers that are used for fuel-tank liners and exposed them to a bacterium and a fungus isolated from fuel tanks. Although the polyurethane coatings did not use oxygen as fast as a nitrile rubber coating, they did decrease in electrical resistivity.

In addition to being used as tank liners, polyurethanes are used as baffles in fuel systems. Open-cell foams cut down the sloshing in tanks and reduce fire hazards on rupture of the tank. Edmunds and Cooney (53) decided that the polyester-based urethanes were not degraded by microorganisms, but did serve as sites for growth. On the other hand, Hedrick and Crum (54) found that some foams were attacked, as indicated by a decrease in tensile strength from an original value of 25 psi to a value of 6 psi after 60 days of exposure to a bacterium and a fungus. It can be seen in Table 4 that the fungus (*C. resinae*) had its greatest effect when both jet fuel and salts were available. This indicates a cometabolic effect.

Darby and Kaplan (50) chose to work with the six fungi recommended by ASTM. It has been mentioned that in their work polyesters supported growth. Tests included a number of diols including polyglycols. Their findings are summarized in Table 5. Polymers were made by reaction of the diols with 4 diisocyanates. As a class, the polyethers were less susceptible to fungal attack. One polymer worth noting is that based on 1,4 butane diol and HDI. This material has been produced since the early 1940's as a fiber-former in Germany (55). The structure is almost like that of nylon 66.



Although only light growth was noted, it is significant considering the paucity of evidence for microbial degradation of synthetic fiber-formers. Some generalizations made by these workers are (50):

"The fact that the polyester polymers of ethylene glycol and 1,3-propanediol are highly susceptible, as contrasted to polyether polymers of these compounds, which are highly resistant, indicates that the polyester linkage is important in the breakdown and metabolism of the former. The weight of the empirical evidence found with commercially prepared formulations supports this conclusion. Adipic acid is well known to be used by fungi for growth, and most of the diols mentioned are also used to a limited extent."

"Although polyester polyurethanes are, as a class, highly susceptible to fungal attack, the polyethers, depending on the diol and diisocyanate used, are also variously susceptible to attack, but to a considerably lesser extent. The presence of at least two, preferably three, unbranched linked methylene groups

Table 4. Tensile-strength (psi) of polyurethane foam specimens (54)

Microbial Isolates	Fluid media and incubation time (days) ^d									
	Fuel		Water		Salts ^a		Fuel + water		Fuel + salts	
	60	90	60	90	60	90	60	90	60	90
<i>Cladosporium resinae</i>	34	27	23	20	19	17	30	15	6	9
<i>Pseudomonas aeruginosa</i>	34	18	23	26	22	29	30	27	29	24
Mixed ^b	28	20	25	20	13	15	16	24	9	9
Control ^c	34	32	33	30	28	27	26	33	29	24

^a Bushnell-Haas mineral salts medium.

^b *C. resinae* plus *P. aeruginosa*.

^c No organisms.

^d At 30 days no significant changes were observed.

Table 5. Maximal growth rating obtained with fungus mixture on (pure) polyurethanes and on constituent monomers (50)

Diol	Monomer	Polymer ^a			
		TDI	MDI	TODI	HDI
<i>Polyethers</i>					
Ethylene glycol	2	0	1	1	0
1,3-Propanediol	2	1	2	1	1
1,4-Butanediol	4	2	2	3	2
2,3-Butanediol	4	2	0	1	1
2-Methyl-1,4-butanediol	4	2	1	1	1
2,2-Dimethyl-1,3-propanediol	3	2	0	1	1
2,3-Dimethyl-2,3-butanediol	2	0	1	1	0
Diethylene glycol	2	1	1	1	0
Triethylene glycol	2	1	1	2	0
Dipropylene glycol	2	0	0	0	0
Polypropylene glycol (mol wt. 400)	2	2	2	2	2
Polypropylene glycol (mol wt. 1,320)	2	3	2	3	2
Bis(4-hydroxyphenyl)dimethylsilane	1	0	0	0	...
<i>Polyesters</i>					
Polyethylene glycol adipate	4	4	4	4	3
Poly-1,3-propanediol adipate	4	4	4	4	3
Poly-1,4-butanediol adipate	4	4	4	4	3

^a 0 = no growth; 1 = trace; 2 = light; 3 = moderate; 4 = heavy growth.

seems to be necessary for fungal attack to occur on polyether polyurethanes."

Fincher and Payne studied bacterial attack of polyethylene glycols (56). The bacterium used was isolated from soil enriched by triethylene glycol. In addition to the glycols of general formula HO-(CH₂-CH₂-O)_n-H, some derivatives were tested. The organism grew well on glycols with *n* up to 9. No growth occurred when *n* was 13 (mol wt = 600) or higher. Both ethyl ethers and acetate esters of lower homologues were attacked indicating that terminal hydroxyls are not necessary.

Most workers report nylons to be fungus-resistant. Pavlov and Akopdzhanyan (57) noted that mechanical and electrical properties deteriorate on exposure, but ascribe this to oxidation or hydrolysis rather than microbial action. On the other hand, Allakhverdiev et al. (58, 59) concluded that deterioration of properties on

burial in soil for a nylon 6 (PK-4 polyamide) was due to fungal attack.

Fukumura (60-64) has isolated 11 bacteria that hydrolyze ϵ -caprolactam, the monomer for nylon 6. At least one of these, *Corynebacterium aurantiacum* B-2, is capable of splitting cyclic trimer, tetramer, and pentamer as well as linear dimer, trimer, and tetramer. The bacteria were isolated from the effluent water line of a nylon 6 plant. The extent to which molecular weight or crystalline form is involved has not been completely explored. Fukumura has investigated many other facets of the system. He has found that vitamin B₁ is required for reaction. Also he has separated two enzymes from the bacterial cells. One enzyme split linear oligomers into 6-aminocaproic acid units. The other hydrolyzes cyclic oligomers as well as the linear oligomers (63).

Protective coatings and biocides

The literature on fungus attack of coatings is quite large (65-71); these works cited contain many other references. Most of the articles deal with the efficacy of fungicides, particularly organic mercury derivatives. The primary criterion of degradation has been discoloration, usually by actual overgrowth. Peeling of the coating and corrosion of the support surfaces also are noted.

In this review, biocides have been given low priority because the objective is to treat biodegradable systems. However, there would be interest in biocides if a useful biodegradable thermoplastic were found. Then a short-lived biocide would be useful. It would protect the fabricated article during its useful life, but degenerate rapidly after the article was discarded.

Biodegradable systems: Possible approaches

So many species of microorganisms occur naturally and so many synthetic polymer structures are possible, that it might seem only a matter of patience to find the "right" combination, as was the case with biodegradable surfactants (72). However, polymers are called upon to fill more numerous and more complex functions than surfactants. It would thus seem unlikely that the most viable approach would involve completely new polymers. This conclusion follows since monomers in current commercial use encompass the simplest and, therefore, probably cheapest of all possible structures. The first attack on the disposal problem therefore implies conventional polymers and new organisms.

The recent discovery of microorganisms that degrade lactams and paraffins gives hope that species may exist that can degrade those polymers that are now made in large volume. If these organisms prove to be viable under ambient conditions, they could be used to inoculate landfills or other areas. Some desirable characteristics of such an organism might be: (a) It should not form spores. That is, it should be a bacterium or yeast, not a mold or actinomycete. The existence of spores, which can remain dormant but alive for long periods and can be air-borne, would make control and localization of infections difficult; (b) It should not be, or be capable of becoming, pathogenic;

and (c) It should be susceptible to some common biocides, once again, for control.

A second potential system would involve a new polymer and a relatively common organism. As indicated, it seems unlikely that a wholly new monomer system would be commercially successful in large volume. However, there may be the alternative of introducing vulnerable points in the polymer chain by using comonomers that can be attacked. This would be similar to the introduction of dye receptor sites into difficultly dyeable fibers. Such sites can be introduced without great alteration in polymer properties. Whether microorganisms could attack these sites is questionable. On the other hand, other environmental conditions may lead to chain rupture at these sites, resulting in low molecular weight fragments that could then be metabolized.

This possibility suggests a stepwise procedure, in which susceptible substructures are discovered, organisms isolated and perhaps mutated, followed by further structural variations. The work of Klausmeier (28) can serve as a model. Low molecular weight esters were used to isolate organisms. Some of these attacked the butylene glycol polyadipate.

Still another approach involves added nutrients, again taken from the work of Klausmeier (28). Here the role of other cofactors than the polymers should be investigated. Some such cofactor might be incorporated in the land-fill or in the fabricated article. A possible candidate would be cellulose or rubber fiber added as reinforcement. It is significant that a great deal of emphasis is now being placed on polymer composites because of their desirable structural features.

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RULES FOR WRITERS

1. Shun and avoid the employment of unnecessary, excess extra words.
2. Make certain all sentences are full and complete. If possible.
3. At all costs, avoid clichés as you would the plague.
4. Take pain's to spell and, pucntuate correctly."
- V. BE Consistent.
6. Don't approximate. Always be more or less precise.
7. Sedulously eschew obfuscatory hyper-verbosity or prolixity.
8. Avoid pointless repetition, don't repeat yourself unnecessarily.
9. Observe, in all written expression, it is, of the foremost qualification-- if not, certainly not or less than-- at least definitely secondary then, the importance, of whenever possibly trying, so that when, except where it cannot be avoided and/or in further necessary development it becomes imperative to omit, yet, remember without fail (for this must not be underestimated) to be brief and clear. This is vital.
11. Always try to remember the ~~#####~~ ~~extreem~~ extreme importance of being accurate nea t and carrful.

Taken by Ray Costa from a long forgotten source...

Biodegradable plastics: An idea whose time has come?

Janis D. Evans
Subhas K. Sikdar

Plastics continue to replace glass and paper in consumer products and packaging materials and to carve their own new markets. The resulting waste is a serious disposal problem that can be solved by (1)

- recycling,
- incineration, or
- degradation in nature.

The plastics industry supports incineration, recycling, and reprocessing and has begun to set standards for reprocessed plastics. But plastic waste is highly disperse, so recycling is only viable for high-cost, low-volume specialty polymers (2, 3). Incineration, effective elsewhere, is not popular in the United States because of safety and unsatisfactory economics when energy is lost (3).

Public concern is on the rise, creating pressures for using degradable plastics, and industry will have to respond to new government regulations being considered throughout the world. Italy has already introduced legislation requiring all plastic packaging materials to be biodegradable by 1991. Other countries are moving in that direction as well (Table 1). The U.S. Department of Transportation has issued a rule prohibiting the dumping of plastic materials in the ocean because of deplorable effects on marine life (4, 5). Thirteen states have either

States with bans or proposed bans on nondegradable plastics

Alaska	Louisiana	North Carolina
California	Maine	Oregon
Connecticut	Massachusetts	Rhode Island
Delaware	Michigan	Vermont
Florida	Minnesota	Washington
Illinois	New Jersey	Wisconsin
Iowa	New York	West Virginia

Companies currently producing degradable plastics

Photodegradable

Ampacet, Mount Vernon, N.Y.
Dow Chemical, Midland, Mich.
Du Pont, Wilmington, Del.
Ecoplastics, Willowdale, Ont.
Ideamasters, Miami, Fla.
Princeton Polymer Labs, Princeton, N.J.
Union Carbide, Danbury, Conn.

Starch additives

Agri-Tech, Gibson City, Ill.
St. Lawrence Starch, Mississauga, Ont.

Biopolymers

Imperial Chemical Industries, Billingham, U.K.

Table 1. Action against nondegradable plastics

Country	Action
Italy	In 1987 Florence banned the sale of all nondegradable plastic food containers. By 1991 all plastics used for nondurable goods must be degradable.
Denmark	Banned nonrecyclable plastic beverage containers and PVC in 1987.
West Germany	Consumer groups have been formed to teach consumers to avoid unnecessary packaging.
Norway	Stores charge consumers for plastic bags to discourage their use.
Canada	Virtually every province is considering bans of some sort.
United Nations	The 1973 Marpole Convention, Annex 5, prevents ocean dumping of plastic wastes.
United States	Gerry Studds (D-Mass.) introduced an omnibus plastics bill that would allocate \$6 million for the study of biodegradable plastics. John Chaffee (R-R.I.) has introduced a bill that would impose a national ban on nondegradable six-pack rings and is pushing for an EPA study on the feasibility of requiring all plastic packaging to be biodegradable. The Senate Foreign Relations Committee is considering a bill that would make dumping plastic waste in U.S. territorial waters a federal offense.

Adapted from Parr, J. *Forbes*, Oct. 5, 1987.



Peter Stackpole LIFE MAGAZINE © 1955 Time Inc.

passed or introduced legislation regulating one or more plastic items.

Demand for degradable plastics is estimated to grow at 75% per year through 1992 to about 400,000 tons and cost \$340 million. By then probably 15% of postconsumer plastic wastes will be biodegradable, compared to a mere 1% in 1987 (6).

In addition to the market created by legislation, degradable plastics are likely to find their niche in agricultural applications such as controlled release of nutrients, fungicides, insecticides, herbicides, and fertilizers. These plastics are uniquely suited to agricultural mulch films, which currently account for more than 100 million pounds of polyethylene sales per year. They are used to improve crop yields by controlling weeds, retaining moisture, and reducing nutrient leaching. However, because polyethylene film cannot be reused and takes 200–400 years to degrade, these films must be removed at a cost of approximately \$100 per acre (7). Obviously, a film that disintegrates during a growing

season would be ideal.

Medical researchers are experimenting with drug-saturated biodegradable plastics for slow-release medication, which permits use of lower doses and provides more efficient and consistent drug delivery (11).

Several companies are taking advantage of the new market (see box) (1), and some have developed plastics that disintegrate within 6 months to 5 years after being placed in a landfill. However, none of the products has been sanctioned by the U.S. Food and Drug Administration for packaging foods. Unfortunately, introducing large volumes of biodegradable plastics may impede recycling efforts, making it harder to distinguish between degradable and nondegradable plastics.

Three approaches to making degradable plastics have long-term potential (1):

- production of photodegradable polymers,
- addition of starch to thermoplastics, and
- production of naturally degradable biopolymers.

Table 2. Polyhydroxybutyrate (PHB) compared with polypropylene

Property	PHB	Polypropylene
Crystalline melting point, °C	175	176
Crystallinity, %	80	70
Molecular weight, daltons	5×10^5	2×10^5
Glass transition temperature, °C	15	-10
Density, g/cm ³	1.25	0.905
Flexural modulus, GPa	4.0	1.7
Tensile strength, MPa	40	38
Extension to break, %	6	400
UV resistance	Good	Poor
Solvent resistance	Poor	Good

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Specifically designed thermoplastics degrade when exposed to sunlight. We can induce this photodegradation by producing a polymer that contains carbonyl groups or by adding various patented photodegradable additives to conventional thermoplastics (1). In the first case, the carbonyl group itself breaks when exposed to ultraviolet light; examples include polymers that combine ketone carbonyl groups with polyethylene, polystyrene, or polypropylene. In the second case, the additives act as catalysts to chain breakdown after exposure to UV light.

Photodegradable technology is highly developed and has been used for years to produce beverage rings, agricultural mulch film, and trash bags. Photodegradable polymers, however, suffer from two problems: the degradable product costs 15% to 20% more than the nondegradable version, and the onset of photodegradation is difficult to control. In fact, most conventional trash bags are colored black to help prevent photodegradation.

An interesting new idea combines biodegradability with photodegradability in polymers that contain azoaromatic units and UV-sensitive ketogroups (8). During use the azo-groups protect the light-sensitive ketogroups. On disposal the azo-groups are attacked by bacteria, releasing ketones and activating photodegradation.

Starch additives

Two processes use a starch additive to make thermoplastics degradable. In both processes the starch particles are eaten by soil microorganisms that help break down the polymer matrix, thereby reducing degradation times. In one patented process a surface-modified hydrophobic starch is added to petroleum-based polymers at 7–15 vol %. The starch is inexpensively derived from cornstarch with 10–12% moisture content, treated with silicones to make it repel water, dried to 1% moisture content, and reacted with surface-treating chemicals to yield the final additive (9). This additive, when combined with an autoxidant, reportedly decreases the degradation times from hundreds of years to as little as four years (10). When polymers prepared with this additive are disposed

of in a landfill, microorganisms attack the starch molecules in the polymer matrix. The autoxidant agent interacts with the metal salts in the soil and produces peroxides that destroy the bonds within the polymer molecule. This process continues until the polymer is completely degraded (10); however, the degradation products in this chemical process have not been characterized.

The starch additive, when used in such small amounts, does not have adverse effects on the quality of packaging materials. In fact, it reportedly has several advantages in addition to biodegradability:

- starch particles are stronger than most plastics, so the addition of starch increases the strength of the overall product;
- cornstarch is less expensive than petrochemicals, so using the additive as a filler has obvious economic advantages;
- the additive's density is comparable to the density of most thermoplastics, so there is little weight difference; and
- less heat is generated when products containing starch are incinerated.

One company that produces this starch additive on a small scale makes mulch films and garbage bags and has applied for a license to produce food containers. Starch addition is similar to the process used to color plastics; therefore, the technology for large-scale production is available. Starch-modified products can be processed using any technique; the only restriction is that injection should be done at less than 232 °C because the polymer begins to degrade at higher temperatures (11).

The second process, developed by the U.S. Department of Agriculture (7), involves addition of 40–60% gelatinized starch to poly(ethylene-co-acrylic acid) (EAA) or combinations of EAA and linear low-density polyethylene. The reaction mechanism is not yet known, but internal bonding within the starch molecule is thought to reduce during gelatinization such that new hydrogen bonds are formed between the EAA carbonyl groups and the starch hydroxyl groups (12). Addition of ammonia increases the

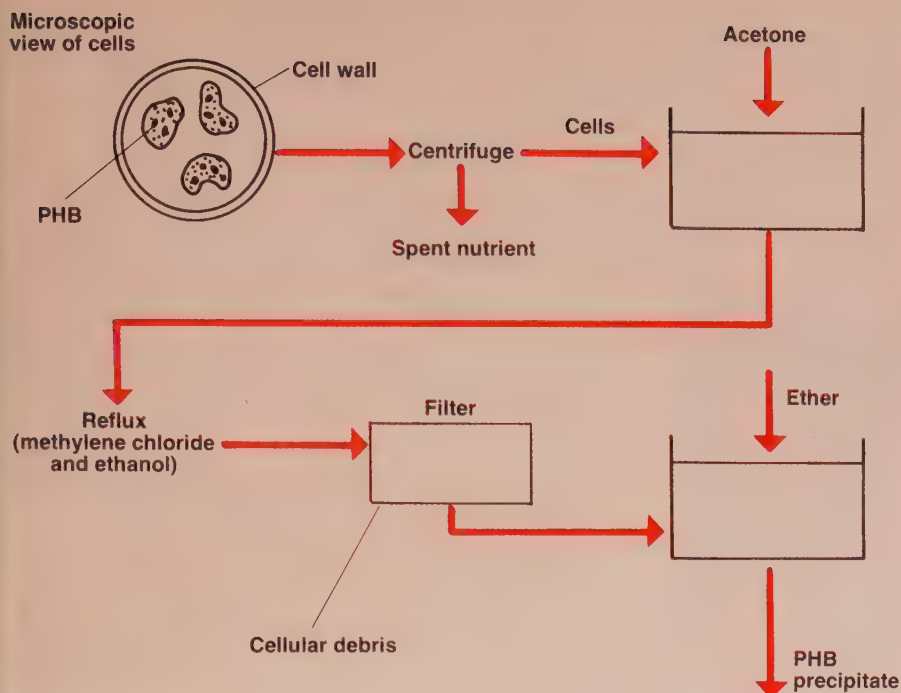


Figure 1. Flow diagram for producing PHB from cells. Reprinted from *Contemporary Topics in Polymer Science*, vol. 5, with permission from Plenum Publishing Corp.

compatibility between the starch and the EAA resin by improving the dispersibility of EAA in water and consequently improving the quality of the films (13). The major disadvantage of this process is the need to premix starch with large amounts of water in the first step. Premixing and the corresponding large volumes of water can be eliminated by incorporating urea into the mix (12).

EAA-starch films are transparent, flexible, and self-supporting. However, the degree of transparency, resistance to UV degradation, and flexibility decrease as the level of starch increases (7). The process will soon be tested on a pilot plant scale. No field studies have been done yet, but degradation times of 12 months for mulch films have been predicted.

Biopolymers

Truly biodegradable polymers are rapidly consumed by soil microbes, resulting in simple compounds. Because hydrocarbon-based plastics are new to the natural world, microorganisms capable of degrading them have not yet evolved in appreciable numbers (14). Some thermophilic organisms can degrade polycarbonate, polyethylene amino, and phenolic thermosets to varying degrees (15). Biodegradation produces harmless products such as carbon dioxide, water, and carboxylic acids. Undoubtedly there are other products, but they remain largely uncharacterized. Starchy materials grafted onto polyethylene are one example of a partially biodegradable polymer.

Research and development on completely biodegradable polymers is fairly active. Poly- ϵ -caprolactone, polylactic acid, and polyanhydrides are commercial examples of truly biodegradable plastics. Poly- ϵ -caprolactone (crystalline m.p. 63 °C, molecular mass 25,000) is degraded by a penicillium strain in 12 days (16, 17). Short chains of aliphatic polyesters and aliphatic polyamides (e.g., nylon) are biodegradable, but aromatic ones are not. A 0.22-mm experimental film of a mixture of

polycaprolactone and nylon has the strength of polyethylene film and is biodegradable (16). Polylactic acid has high strength but lacks the desired moisture resistance and hydrolytic stability. Other potential compounds include copolymers of lactic acid and glycolic acid, and block copolymers of lactic acid with butadiene, styrene, and ethylene (18).

For packaging applications, by far the most promising possibilities today are based on polyhydroxybutyrate (PHB) and polyhydroxyvalerate (PHV). *Alcaligenes eutrophus*, when deprived of nitrogen, phosphate, magnesium, or sulfate, produces poly(3-hydroxybutyrate) to 90% of the bacterial dry weight (19). As a polymer, PHB compares well with polypropylene (Table 2) in terms of molecular mass, melting point, crystallinity, and tensile strength. Because of its poorer solvent resistance, PHB cannot be used in applications where it will come into contact with solvents. However, the major drawback of PHB, which limits its usefulness as a biodegradable substitute for polypropylene, is its low-impact strength. PHB completely degrades in two months (20).

A copolyester of hydroxybutyric and 3-hydroxyvaleric acids, isolated from *Alcaligenes eutrophus*, showed greater potential (21). Fortunately, impact strength, flexural modulus, and crystallinity can be regulated simply by changing the amount of poly(3-hydroxyvalerate) PHV in the PHB-PHV copolymer (21, 22). The crystalline melting temperature, however, decreases rapidly with the addition of PHV (23). Copolyesters of 3-hydroxybutyric acid and 4-hydroxybutyric acid also offer useful mechanical properties in molded parts and cast films (24).

Numerous procedures have been described for isolating PHB from cells. Figure 1 shows one patented procedure (25). In this process, the cells containing PHB particles are centrifuged to remove spent nutrients and then washed with acetone, methylene chloride, and ethanol to extract the PHB. This stream is filtered to remove cellular debris. Finally the PHB is precipitated with ether. A similar

continuous extraction procedure allows for the recovery and reuse of solvents to produce copolymers of PHB-PHV (26). Current production costs are \$7/kg; however, in the near future, use of a commercial plant is expected to cut production costs to 50 cents/kg. The polymer is now used for films, sterilized medical dusting powders (27), and fibers (28).

Because PHB-PHV polymers occur naturally, there are enzymes that degrade them. One enzyme, poly(3-hydroxybutyrate) depolymerase, has been isolated from *Alcaligenes faecalis* (29). In general, most β -substituted polyesters are degradable by some fungi after hydrolysis in acidic or basic media (30).

Conclusion

Biodegradable plastics are finding new markets due to environmental legislation and the development of specialty applications. But technology is not yet keeping up with increasing demand. Several major producers are marketing photodegradable products, but only a handful of small companies actually produce items made with biodegradable polymers. The two most promising processes currently available for making these polymers are the addition of starch to conventional thermoplastics and microbial production of the entire polymer. Both of these processes are still in the developmental stages. Considering the growing gap between demand and production technology, research on biodegradable plastics promises to be an exciting and profitable new area for the chemical industry.

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An unimportant issue is one about which you are ashamed to admit you have no knowledge.

Sign on the Universalist
Church of New York

Mit der Dummheit kämpfen Götter selbst vergebens
(from Act III, Scene 6 of *The Maid of Orleans*, by
Friedrich V. Schiller). Translation in *Bartlett's
Quotations*: "Against stupidity the very gods
themselves contend in vain."

The superconducting super collider

Forty years ago, ordinary matter was thought to consist of protons, neutrons, and electrons. Experiments probed the structure of these particles and explored the forces that bind them into nuclei and atoms. In the course of these experiments, physicists discovered more than a hundred new particles, called hadrons, which had many similarities to protons and neutrons. None of these particles seemed more elementary than any other, and there was little understanding of the mechanisms by which they interacted.

Gradually, a radically new and simple picture emerged as a result of many crucial experimental discoveries and theoretical insights. It is now clear that the proton, neutron, and other hadrons are not elementary. Rather, they are composite systems made of much smaller particles called quarks, much as an atom is a composite system made up of electrons and a nucleus. The existence of five kinds of quarks has been established, and initial experimental evidence for a sixth species has been reported.

Unlike our view of the proton and neutron, our view of the electron as an elementary constituent of matter that is structureless and indivisible has survived the revolution intact. However, we now know that there are six kinds of electronlike particles called leptons. Both quarks and leptons appear to be grouped in three families of two members each. According to our present understanding, then, ordinary matter is composed of quarks and leptons.

The world around us is made of just three of those fundamental particles—the two lightest quarks and the electron. The other elementary constituents of matter are created under extreme conditions such as may exist in collisions of energetic particles either in cosmic rays, accelerator beams, or interiors of exotic stars. They presumably were present in abundance some 15 billion years ago in the early stages of the creation of the universe.

For half a century, physicists have recognized four basic forces: gravitation, electromagnetism, the weak interaction responsible for certain radioactive decays, and the strong force that binds atomic nuclei. An important difference between quarks and leptons is that one of these four interactions, the strong force that binds quarks

The goals of particle physicists are a natural continuation of a perpetual human quest. The belief that the universe is rational, that matter is composed of relatively few simple constituents, and that the laws governing them are fundamentally simple and comprehensible to the human mind has pervaded the history of science in the Western world. These ideas were confirmed by the theoretical and experimental advances achieved by scientists in the 19th century. The periodic table of Mendeleev, a systematic organization of the information obtained up to that time on the nature of matter, is in some sense a summary of their achievements. The modern phase of physics began at about the same time with the study of atomic emission and absorption lines in the visible spectrum and the discovery of the electron.

together to form hadrons, does not affect leptons. Both quarks and leptons are acted on by the three other fundamental forces.

During the past two decades, great progress has been made in understanding the nature of the strong, weak, and electromagnetic forces. The weak and electromagnetic forces have been unified by a theory whose predictions have been verified by many inventive experiments, the culmination of which was the discovery of the *W* and *Z* particles in 1983. These carriers of the weak force are analogs of the photon, the carrier of the electromagnetic interaction, whose existence was postulated early in this century and established experimentally by the middle 1920s. In addition, there is indirect but persuasive evidence for particles called gluons, the carriers of the strong force. The strong, weak, and electromagnetic interactions are all described by similar mathematical theories called gauge theories. At present, the role played by the gravitational force in elementary particle physics is unclear. The effect of gravity on the behavior of elementary particles is so small that it usually can be ignored.

The experimental measurements and discoveries that shaped the revolution in particle physics were made possible by harnessing new accelerator and detector technologies that permitted the exploration of new energy domains in novel and incisive ways. Each sortie into a new energy regime, each improvement in our ability to search for rare processes, and each increase in sensitivity for their detection has led to new insights and, often, to the discovery of unexpected and revealing phenomena.

With the identification of quarks and leptons as elementary particles and the emergence of gauge theories as descriptions of the fundamental interactions, we possess today a coherent point of view and a single language

Editor's note

This article is based on the *Research Briefings* produced by a joint committee of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. Experts in each field report on the state of the art and challenges for future research. Because some of the briefings came out some time ago, we'll include an update to indicate what progress has been made and the new directions each field is taking.

appropriate for the description of all subnuclear phenomena. This development has made particle physics a much more unified subject, and it has also helped us to perceive common interests with other specialties. One important byproduct of recent developments in elementary-particle physics has been recognition of the close connection between this field and the study of the early evolution of the universe from its beginning in a tremendously energetic primordial explosion called the big bang. Particle physics provides important insights into the processes and conditions of the early universe. Deductions from the current state of the universe can, in turn, give us information about particle processes at energies that are too high to be produced in the laboratory—energies that existed only in the first instants after the primordial explosion.

What we want to know

Developments in elementary-particle physics during the past decade have brought us to a new level of understanding of physical laws, often called the standard model of elementary-particle physics. As usual, the attainment of a new level of understanding refocuses attention on old problems that have refused to go away and raises new questions that could not have been asked before. The quark model of hadrons and the gauge theories of the strong, weak, and electromagnetic interactions organize our present knowledge and provide a setting for going beyond what we now know. A useful analogy can be made between our present-day understanding of elementary-particle physics and the situation in atomic physics in the early 20th century.

The Bohr model of the hydrogen atom was a radical idea that initiated a revolution not only in the field of atomic physics but also in our whole philosophical approach to physics. By incorporating into one theory a new concept of quantization of angular momentum together with the classical ideas of electrodynamics, Bohr succeeded in creating a formalism that successfully explained the observed spectral lines of hydrogen. But the model had obvious difficulties. Not only did it fail to predict the spectra of more complicated atoms, but it also left unresolved the fundamental question of why the electron does not fall into the center of the atom by radiating away all its energy. Nevertheless, on the basis of its partial success, scientists believed that the ultimately correct theory would almost certainly contain some of the ideas embodied in the Bohr theory.

Particle physics may be in a similar situation today. Although the standard model provides a framework for describing elementary particles and their interactions, its success prompts us to seek a more comprehensive understanding. For example, we do not know what determines such basic properties of quarks and leptons as

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their masses. Nor do we understand fully the origin of the differences between the massless electromagnetic force carrier (the photon) and the massive carriers of the weak force (the W and Z particles). Existing methods for dealing with these questions involve introducing many unexplained numerical constants into the theory—a situation that many physicists find arbitrary and thus unsatisfying. Physicists are actively seeking more complete and fundamental answers to these questions.

Another set of questions goes beyond the existing synthesis. For example, how many kinds of quarks and leptons are there? How are the quarks and leptons related, if they are related? How can the strong force be unified with the already unified electromagnetic and weak forces?

Then there are questions related to our overview of elementary-particle physics. Are the quarks and leptons really elementary? Are there yet other types of forces and elementary particles? Can gravitation be treated quantum mechanically as are the other forces, and can it be unified with them? More generally, will quantum mechanics continue to apply as we probe smaller and smaller distances? Do we understand the basic nature of space and time?

Given this list of questions, it is not surprising that theoretical speculation often departs from the current paradigm. Many of these speculations imply important

phenomena at energies that are at present beyond our reach. Although theoretical speculation and synthesis are valuable and necessary, particle physics cannot advance without new observations. In the recent past, crucial observations have come from a variety of sources, including experiments at accelerators and nuclear reactors, nonaccelerator experiments (cosmic-ray studies and the search for proton decay), and deductions from astrophysical measurement. Our current ideas, embodied in the standard model, point to 1 trillion electron volts (1 TeV is an energy equivalent to approximately 1000 proton masses) as the energy scale on which new phenomena can be expected. But a diversity of experimental initiatives will have to be mounted to explore thoroughly the new regime of energy and distance. The super collider, with the wealth of different experiments that it would support, is the instrument of choice for exploring this new domain. At the same time, these extensions of the standard model set the parameters for the new accelerator.

Not the only game in town

The super collider will not be the only source of new information. The accelerators currently under construction (like the electron-positron colliders at the Stanford Linear Accelerator Center and the European Organization for Nuclear Research (CERN), and the Tevatron proton-antiproton collider at Fermi National Accelerator Laboratory) will provide detailed quantitative tests of the standard model and its relation to cosmology. More sensitive proton decay experiments, better neutrino mass measurements, improved searches for monopoles in cosmic rays, and more precise searches for forbidden decay processes are examples of other important lines of non-superconducting super collider investigations that will continue to be pursued. However, according to our present knowledge of elementary-particle physics, our physical intuition, and our past experience, most clues and information will come from experiments at the highest energy accelerators.

A major accelerator facility is not constructed to carry out a single experiment or measurement but rather to make possible a great diversity of investigations over the decades of the accelerator's life. The experimental program is guided by results of early experiments, by improvements in detector and accelerator technology, and by theoretical insights. Because of this, we cannot describe in advance the full scope of the research program for a super collider. The scientific justification for constructing a super collider and the opportunities that a super collider would present involve addressing some of these basic concepts:

Origin of mass. Imagine a universe pervaded everywhere by a uniform magnetic field. In such a universe, the motion of charged particles would appear to

be rather complicated because the particles' motions would be influenced by the universal magnetic field as well as by specifically applied forces. Eventually, as physics developed, some genius would realize that a simple law of motion (namely Newton's) is really the basic one and that all the complicated spiralings observed in his universe are caused by a pervasive background field.

The Higgs field

The current standard model of the weak interactions suggests that a similar situation is realized in our universe. The field involved is not a magnetic field but rather what is called a Higgs field. The equations describing the weak interactions would take a simpler and more symmetrical form if there were no background Higgs field. One simplification that would occur is that the masses of the *W* and *Z* bosons and of many other particles would vanish. This simplification evidently goes too far for the real world. The best we can do is to postulate that the basic model operates in a world pervaded by a background Higgs field that partially hides its full symmetry and simplicity. The standard model, with this standard assumption, accurately describes a wide variety of observations—including the existence and mass of the *W* and *Z* bosons recently found at CERN—but requires the existence of one or more scalar particles associated with this background field.

Certainly one main area that we can hope to clarify with the super collider is the exact nature of the Higgs field and its interactions with other matter. Why is the super collider likely to be an appropriate tool? Consider the reason that the Higgs field pervades our universe. It must be because the total energy density is minimized by having this field present. To change the magnitude of the field significantly, or make manifest one of its particles, we must supply enough energy density to overcome the natural tendency of the field to revert to its normal universal background value. We estimate that the energies that would be available at the super collider are almost certainly sufficient to do so.

Families. The recent discovery of the third family of quarks and leptons has sharpened the problem of understanding the replication of particles in families. Three families of elementary particles are known that have, within a very well-defined sense, identical strong, electromagnetic, and weak interactions but different masses. Why does nature repeat itself in this way? Are there still more families? Do Higgs particles come in families? Are there other particles that do not fit into the same repetitious pattern?

One theoretical approach to understanding the existence of families postulates the existence of symmetries under which the different families are interchanged. Given such symmetries, the existence of one family

The design

The super collider would have two counter-rotating beams of protons guided by superconducting magnets. Each beam would be accelerated to 20 TeV, and the two beams would be allowed to collide. Six different collision points around the circumference of the main ring are proposed in current designs.

The proposed accelerator scheme makes use first of an injector system consisting of a linear accelerator followed by two circular accelerators. This system accelerates protons to about 1 TeV, at which point they are injected into the main ring for the final acceleration phase. The diameter of the main ring will be somewhere between 30 and 50 km, depending on the strength of the magnetic field in the magnets chosen for the super collider. Several different magnet styles are under consideration. The eventual choice of magnet style will be made with the objective of minimizing the construction and operating costs of the machine and maximizing its reliability.

All the segments under consideration use the superconducting technology and cryogenic systems first successfully employed on a large scale at the recently completed Tevatron ring at the Fermi National Accelerator Laboratory. Superconducting magnets make the super collider feasible by significantly reducing the required power consumption and enabling one to achieve higher field strengths than are offered by conventional room-temperature magnets.

Current super collider designs use proven technology on a vast scale. The linear dimensions of the super collider would be at least 15 times larger than those of the Tevatron, and 3 to 5 times larger than those of the collider currently under construction by CERN. The Tevatron requires about 1000 superconducting magnets, whereas the super collider would employ perhaps as many as 14,000. This very large scale presents challenging problems in such areas as manufacturing techniques, quality control, reliability, civil engineering, instrumentation and controls, communications, and installation and repair logistics. The magnitude of these problems is rather new to accelerator science and technology but manageable by an appropriate extension of present skills and experience. Creative solution of these problems calls for a new partnership between the basic research community and industry, which may bring important advances in technology of practical value.

The detectors provide another great challenge to the experimentalists. Only a tiny fraction of the 10^8 interactions occurring every second will be of interest. The techniques necessary to identify and record these interesting events in a small fraction of a second will advance the frontiers of electronics and computer technology.

necessarily implies the existence of others. A particularly appealing version of this idea involves combining the family symmetry and the gauge symmetries of the strong, weak, and electromagnetic interactions into one gigantic, all-encompassing symmetry, hidden by the presence of suitable background Higgs fields.

Supersymmetry. Many theoretical investigations have

explored the physical consequences of a radically new kind of symmetry called supersymmetry, which implies the existence of integral-spin replicas or partners of particles of half-integral spin, and vice versa. If it is relevant to physics at all, supersymmetry must be a broken symmetry—for example, there is definitely no particle having the mass and charge of the spin- $1/2$ electron that has integral spin. Such a particle would have been observed long ago if it existed.

There may be significant advantages to the view that supersymmetry is not too badly broken, so that many supersymmetry partners of known particles could be produced at super-collider energies. These advantages include resolution of the mathematical inconsistencies arising in the calculation of many physical quantities—specifically the masses of the Higgs particles.

Significant progress has been made recently in building unified field theories that include gravity. These ambitious theories, which incorporate supersymmetry in a fundamental way, involve objects called superstrings; they will be confirmed, significantly constrained, or ruled out by experiments that elucidate the possible role of supersymmetry at super-collider energies.

Compositeness. Violent collisions among quarks also provide a window on the possible internal structure of quarks. Some physicists feel that the known quarks are themselves too numerous to be the ultimate elementary particles. If quarks themselves are composite, it should be possible to excite their internal structure in violent collisions. One sign of this kind of internal excitation would be spectacular events quite unlike those anticipated in the standard model. The absence of such events and the agreement of the observed quark-quark scattering cross section with the standard-model predictions imply upper limits on the size of quarks. It will be possible with the super collider to look for quark substructure down to a distance of about 10^{-8} cm.

Both general arguments and specific conjectures for resolutions of the Higgs problem imply 1 TeV as an energy scale on which new phenomena crucial to our understanding of the fundamental interactions must occur. The origin of electroweak symmetry breaking is only one of the important issues that define the frontier of elementary-particle physics. However, because of its immediate and fundamental significance, it must guide our planning for future facilities.

Cosmology. During the past few years, cosmology and particle physics have become increasingly interwoven. To understand the physics that took place in the high-temperature, high-density early universe, one is forced to look at the physics of elementary particles. Similarly, the unified theories of elementary-particle physics have striking consequences at extremely high temperatures and

Update

In early 1989, the Department of Energy selected a site for the SSC Laboratory in Ellis County, Texas, about 30 miles south of Dallas. A team headed by the Universities Research Association (a consortium of 69 major research universities) and including EG&G Incorporated and Sverdrup Corporation was chosen to manage the construction and operation of the SSC. The magnitude of the undertaking is shown in the numbers of Table 1.

Roy F. Schwitters is the director of the laboratory. When completed, the campus area associated with the SSC will have fifteen or more buildings to accommodate the 2500 staff and 500 visiting scientists who are using the facility.

In the SSC, protons will pass first through a linear accelerator, and from there will enter a series of 3 booster rings which will take in protons at one energy and feed them, at higher energy, to the next stage. The protons will enter the main ring at 1 TeV, where they will be pushed to 20 TeV prior to collision in one of the 4 interaction halls (Figure 1). Superconducting magnets will keep the proton beams on track.

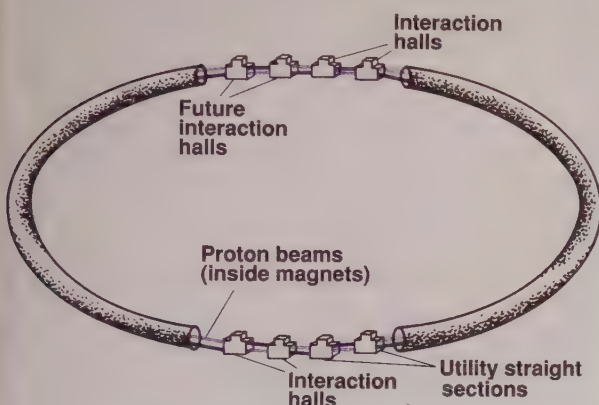


Figure 1. Proposed layout for the SSC

Table 1. The SSC numbers

Physics parameters:	
Proton energy	20 TeV
Number of protons per ring	130 trillion
Collisions per second	100 million
Dipole magnets:	
Number per ring	3840
Length	17.34 m
Weight	6759 kg
Quadrupole magnets:	
Number per ring	888
Length	4.32 m
Weight	1114 kg
Main ring:	
Circumference	82.944 km
Number of magnets (including all special purpose magnets)	10104
Weight of iron in magnets	41,500 tons
Total length of superconducting cable	19,400 km
Refrigeration:	
Quantity of liquid helium	2 million liters
Quantity of liquid nitrogen	1 million liters
Cost: (1988 dollars)	
Total construction cost (spread over 8 years)	\$3,210 million
Additional costs (detectors, computers, R&D, etc.)	\$1,000 million (approx.)
Operating costs	\$270 million/year

energies. The only laboratory available to check these extrapolations of unified theories is the first instants after the big bang, when extraordinarily high temperatures and densities were reached. In some ways, the two fields have become symbiotic. The super collider will operate at energies far beyond those previously achievable in a laboratory and will simulate the conditions that prevailed when the temperature of the universe was about 10^{17} K. These conditions occurred about 10^{-15} s after the primordial explosion. Direct observations by optical telescopes are limited to events that occurred roughly 300,000 years after the big bang because the universe was opaque to photons at earlier times.

To explain the universe

To reconstruct what occurred in the early universe, it is necessary to know the nature of fundamental interactions at high energies and the complete spectrum of elementary particles. In particular, the relics left over from those early times are of fundamental importance to cosmology. Any long-lived particle produced in the primordial explosion would survive and be an ingredient in the present-day universe.

One of the major issues in cosmology is to find the dark matter of the universe. Studies of the motion of stars within the galaxies and of galaxies within clusters have established that these systems must contain a great deal of matter in addition to what is visible in the stars. This nonluminous matter may in fact account for the bulk of the mass in the universe. The properties that we impute to the dark matter depend on the character of the small density fluctuations in the early universe that grew into the galaxies and clusters observed today. According to current ideas on galaxy formation, the dark matter may be quite different from the ordinary (baryonic) matter of which we are made. Particle physics yields a mechanism for generating the primordial density fluctuations and provides candidates for the dark matter as well. Experimentation at the super collider will allow broad searches for new particles that may play the role of the dark matter.

The advances of the past decade have brought us tantalizingly close to a profound new understanding of the fundamental constituents of nature and their interactions. The standard model based on quarks and leptons organizes our current knowledge and defines the frontier of particle physics at constituent energies of about 1 TeV and the frontier of cosmology at times of about 10^{-15} s. There we await new discoveries about the unification of the forces of nature, the patterns of the fundamental constituents of matter, and the origin of the universe.

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New technology and chemical feedstocks

Harold A. Wittcoff

Chemical industry feedstocks are changing. Such changes in a "mature" industry are unusual. The industry's outlook has brightened considerably during the past three years due to massive restructuring in Western Europe, the United States, and Japan, coupled with unmet needs. If all goes well, this upswing will continue for several years. But even so, we must recognize the industry's maturity when it comes to large-volume, basic chemicals, commodity polymers, and even certain specialties. Despite the maturity of the industry, some changes arise from development of new technologies, particularly those technologies that permit substituting alkanes—ethane, propane, and butane—for their corresponding olefins or technology related to the functionalization of methane. But in most instances change results from dislocations taking place outside the industry.

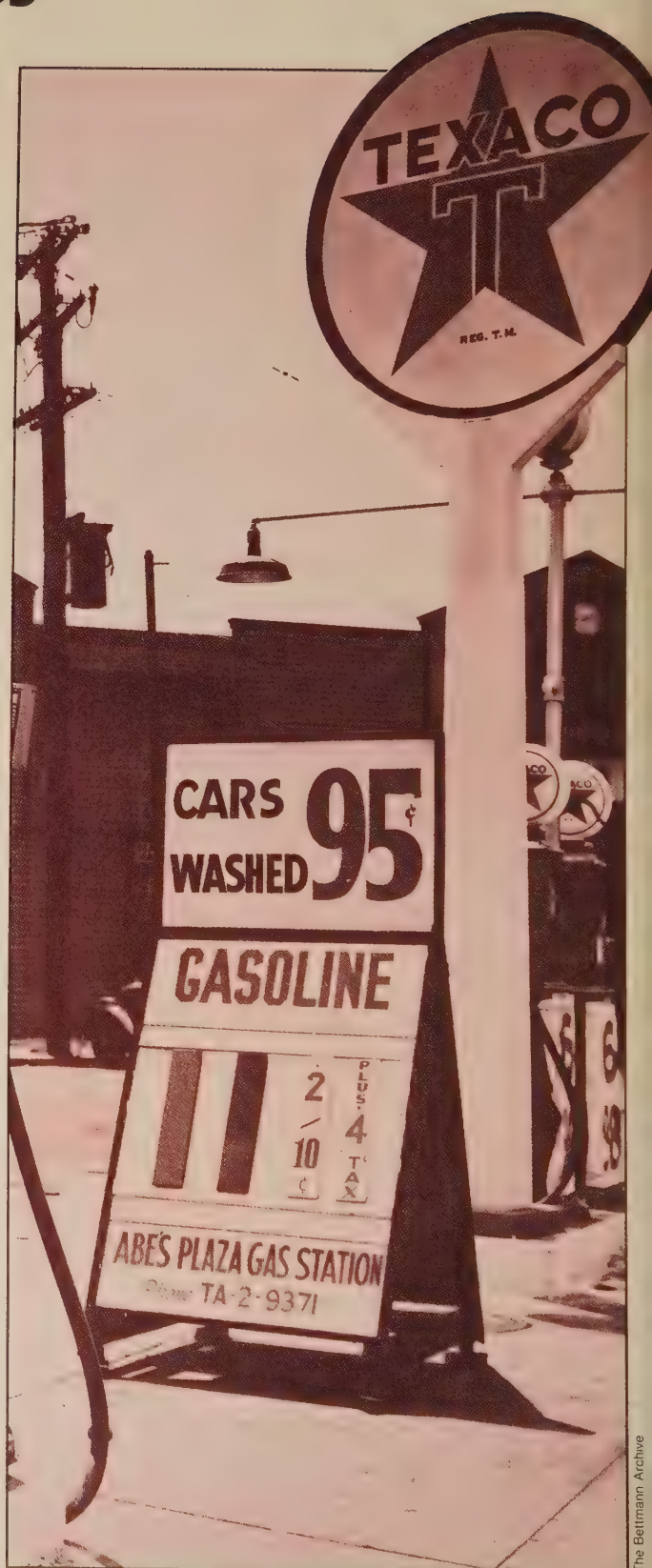
What are some of these dislocations? I'll single out five:

- the shift to unleaded gasoline
- environmental considerations
- the drive for cheaper feedstocks
- actual or potential shortages of basic raw materials
- the potential exhaustion of petroleum

It is interesting to compare the chemical industry of the early 1960s with the chemical industry today (see Table 1). As in all phases of human endeavor, it is not unusual to refer to the industry of a quarter-century ago as "the good old days." The changes seen during the past 25 years reflect themselves in almost every aspect of the chemical industry, including feedstocks.

For the chemical industry, one of the most interesting results of the shift to unleaded gasoline is the need to strip naphtha to remove the C_5 and C_6 hydrocarbons prior to catalytic reforming. These compounds tend to hydrocrack irreversibly to gaseous products under catalytic reforming conditions and to give low yields of aromatics. Also the benzene that is obtained from the C_6 compounds is an unwelcome component of unleaded gasoline, not only because its octane number is lower than that of the more highly methylated compounds but also because it is toxic.

Thus the C_5 - C_6 fraction from naphtha becomes a new raw material for the chemical industry and has three possible uses, two of which are well established: its use as cracking stock for olefins, and its isomerization to produce



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**Table 1. Chemical industry
The players**

Yesterday	Today	Tomorrow
United States	add	add
Western Europe	Saudi Arabia	Malaysia
Japan	Canada	Burma
	Mexico	Argentina
	Venezuela	Australia
	Brazil	Chile
	Trinidad	Kuwait
	Indonesia	
	New Zealand	
	Eastern Bloc	
	Korea	
	Taiwan	

The characteristics

Characteristics	Yesterday	Today
Growth	Always up	Cyclical—varies with GNP— sometimes unpredictable
Prices	Stable to declining	Rapid rise and fall
Process economics	Bigger is better— economy of scale	Logistical issues—purchasing, manufacturing, distribution, marketing —all affect size
Technology	Chemical engineering	Multidisciplinary—material science (composites, ceramics), biotechnology, electronics, computer engineering, waste management, ecology
R&D management	Relatively easy	Complex—what to emphasize, innovate or follow, avoidance of duplication, go it alone? . . .
Risk	Predictable	Unpredictable

branched products useful in nonleaded gasoline. It is of particular interest as a cracking stock in the United States because it produces more propylene and C₄ olefins than does the ethane and propane conventionally cracked, although the refinery must be equipped to process the coproducts. Also the C₅–C₆ fraction is easier to handle than gas oil and naphtha, which are assuming greater importance in the United States as the supply of gaseous feed decreases.

Table 2 provides a forecast of how feedstocks for steam cracking will change during the next decade in the United States and in Western Europe. Traditionally the United

States has enjoyed an economic advantage because of the availability of cheap gaseous feedstocks. Note that at least a portion of the advantage will be lost as the industry shifts to liquid feeds. The C₅–C₆ fraction, because it is easy to handle, may resemble in profitability the gaseous feeds more than the liquid ones.

A second use for this fraction is in isomerization. Isomerization of a typical light naphtha with an octane number in the range of 65–70 (1/2 [research + motor octane]) provides a product with an octane value between 78 and 84.

A third use currently under development involves

Table 2. Feedstocks for ethylene. United States vs. Western Europe

Feedstock, % of total	1982		1985		1995 Projected	
	United States	Western Europe	United States	Western Europe	United States	Western Europe
Ethane/propane	72	—	65	—	52	—
Ethane/propane/butane	—	9	—	14	—	19
Naphtha/gas oil	28	91	35	86	48	81

catalytic reforming of the C₆ fraction to benzene. Rather than using the conventional platinum or rhenium catalysts, a 7–9 Å large-pore X-, Y-, or L-type zeolite is employed. Catalysts of this type eliminate the undesirable hydrocracking that occurs with the conventional catalysts. Chevron, Exxon, UOP, and Elf have been active in developing this technology. In some instances selectivities close to theoretical values have been obtained.

Still another new process—the Cyclar process—originated at least in part from the need for aromatics for unleaded gasoline. In this process, developed by BP and UOP, liquefied petroleum gas is reformed to aromatics in the presence of a gallium-doped zeolite catalyst. The process may actually use ethane, but the pilot plant currently under construction is intended for a mixture of propane and butane. Conversions of 65–95% have been reported, with selectivity to aromatics of 50–65% with C₄ feedstock. The process deactivates the catalyst rapidly, which necessitates continuous regeneration, a technology with which UOP has had considerable experience. Table 3 shows the value of the aromatics produced by the Cyclar process using liquefied petroleum gas as a feedstock. A value of 82.8 cents/gal compares favorably with that of aromatics produced by catalytic reforming, and provides a simple return on investment of 10.3. This could improve if aromatics value in unleaded gasoline increases. The process also is of interest in countries that crack primarily ethane, such as Saudi Arabia, and thus have no traditional source of aromatics either from the catalytic reforming of naphtha or from the pyrolysis gasoline that results from the cracking of liquid feedstocks.

Basic to performance in the modern chemical industry is concern for the environment. In the United States one aspect of this is EPA's concern about the environmental problems resulting from the inclusion of *n*-butane in gasoline, particularly during summer months in areas where the temperature is high. Accordingly EPA has proposed that during a five-month summer period the butane content of gasoline be lowered in certain areas and eventually eliminated. This would mean that by June 15, 1999, during that five-month period 200,000 bbl/day of butane would become available. This figure translates to 7.86 billion lb. and is roughly half the amount of *n*-butane

Table 3. Value of aromatics produced by the Cyclar process, fourth quarter, 1987, U.S. Gulf Coast

Total investment	\$135 million
Cash cost of production	68.7 cents/gal
Product value	82.8 cents/gal
Cash margin	14.1 cents/gal
Simple return on investment	10.3 %

Aromatics valuation

Aromatic	Vol %	Price, cents/gal
Benzene	34.3	95
Toluene	46.4	77
Xylene	19.3	75
Weighted average value		82.8

used in gasoline. It has been estimated that approximately 4.8 billion lb. of this total could become steam-cracker feed. All of it will not be used because much *n*-butane is imported into the United States, and some of this importation will cease. The cracker processing *n*-butane, like the one using the C₅–C₆ fraction of naphtha, must be equipped to isolate the coproduct propylene and C₄ olefins.

The drive for cheaper feedstocks

In a mature industry there is always important incentive for finding cheaper feedstocks. The difference in price between the alkanes—ethane, propane and butane—and the corresponding olefins made from them—ethylene, propylene, and the butylenes—can frequently be as much as 10 cents/lb. On the other hand, the saturated materials are loath to enter into the chemical reactions that provide the basic chemicals now derived from olefins. Much work has been done on the conversion of ethane to vinyl chloride and propane to acrylonitrile. We at Chem Systems believe that both processes show considerable promise.

The catalytic oxidation of *n*-butane to maleic anhydride is the best example of the use of alkane to obtain a functional compound in high selectivity. The key is the catalyst, for oxidations tend to give many products and

Table 4. Maleic anhydride production costs^a

	Benzene process	<i>n</i> -butane ^b fixed-bed process	<i>n</i> -butane ^c fluid bed process
Capital cost, millions of dollars	29.60	38.10	34.10
Cost of production, cents/lb.	3.00	2.50	2.50
Net raw materials	16.55	12.18	11.03
Utilities	0.08	0.40	(0.002)
Operating costs	3.33	3.87	1.96
Overhead	3.45	4.01	1.48
Cash cost	23.41	20.46	14.47
Depreciation	7.98	10.12	6.03
Net cost of production	31.39	30.58	20.80
Price to yield 10% return on capital	38.28	38.74	25.62

^a Basis: U.S. Gulf Coast, 1987, 60 million lb./year.

^b Fixed-bed process with water-based recovery of product. Most widely used.

^c Du Pont/Monsanto transport bed process with solvent-based recovery of product.

Steam cracking

Catalytic cracking (refinery)

Propane dehydrogenation

Metathesis (ARCO)



Methyl alcohol cracking (zeolite catalyst)

Figure 1. Sources of propylene

correspondingly low selectivity. Typical catalysts for this oxidation include phosphorus, vanadium, lithium, and zinc. Typical yields are 50–52% per pass. Side reactions lead to CO₂ and H₂O. That there is still room for technological achievement in a mature industry is shown by a process for butane oxidation to maleic anhydride announced recently by Du Pont. Its patents claim an amazing 72% yield per pass. This means that the yield has been improved in one giant step by roughly 40%. The catalyst described is made of vanadium and phosphorus oxide, with a promoter of silicon and either indium, antimony, or tantalum. Du Pont's contribution includes not only the catalyst but also the fact that the reaction is carried out with only the catalyst's chemically bound oxygen. This requires constant regeneration of the catalyst, so a transport bed process is used. Table 4 compares the cost of producing maleic anhydride by the Du Pont process to the benzene-based process, which is obsolete in the United States, and to the fixed-bed process with the conventional catalyst—the process most widely used today.

Effect of shortages

For various reasons shortages of propylene have occurred during the past three years, and even greater

shortages may occur in the years to come. For more than two decades, starting in the late 1950s, the price of propylene was always a comfortable 20% below that of ethylene. But at times in 1986 the price of propylene in both the United States and Western Europe equaled that of ethylene, and in February 1987 the price of propylene in Western Europe was 15 cents/lb., compared with 12.9 cents/lb. for ethylene. The recent increase in the price of ethylene has reversed that situation, but there is still a feeling—motivated in part because the processes that use propylene derivatives are less mature than those of ethylene and will grow faster—that a propylene shortage may develop. In addition, no propylene is produced in countries where only ethane is being cracked. Several new processes have been proposed for propylene production. The most important is propylene dehydrogenation (Figure 1). This process makes use of a catalyst comprising alumina–chromia on supported and promoted platinum or tin and follows the well-established technology for dehydrogenating butane or butenes to butadiene.

ARCO has announced the use of reverse metathesis for propylene production starting with ethylene. Ethylene is dimerized to 2-butene, and this undergoes the metathesis reaction with more ethylene to give propylene. This reaction is probably not practiced today because of the wide disparity in propylene and ethylene prices. A third process involves the cracking of methyl alcohol in the presence of a zeolite catalyst to provide an olefin mixture high in propylene content. This process was seriously considered two years ago, when there appeared to be a large excess of methyl alcohol in the world. Somehow that excess has disappeared, and cheap chemicals based on methyl alcohol are not currently in the offing.

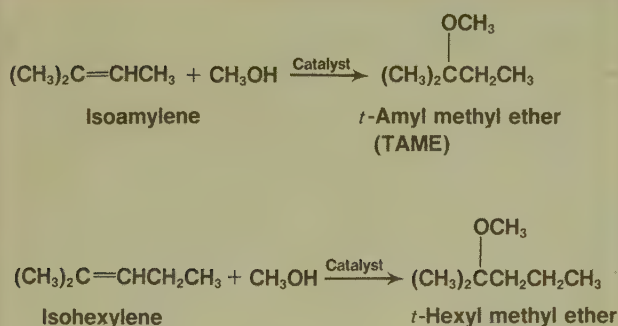
Another raw material that promises to be in short supply in the early 1990s is isobutene, the starting material for the important unleaded gasoline additive methyl *t*-butyl ether (MTBE). Here again we see a dislocation attributable to unleaded gasoline. Table 5 shows both the actual and projected growth of MTBE, the fastest growing chemical

Table 5. MTBE demand, billion pounds

Year	U.S.A.	Western Europe
1976	—	0.15
1981	—	0.64
1984	1.38	—
1985	1.89	—
1986	2.24 ^a	1.78 ^{a,b}
1987	3.37 ^a	—
1990	4.80 ^{a,b}	3.52 ^{a,b}

^a Estimated.

^b Includes imports.



Function 1: Double bond shift to enhance reactivity

Function 2: Highly selective hydrogenation of diolefins to monoolefins

Function 3: Etherification

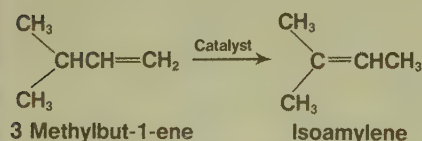


Figure 2. (a) BP's Etherol process. Unsaturated hydrocarbons in fluid catalytic cracking react with methyl alcohol. (b) Functions of the Etherol catalyst

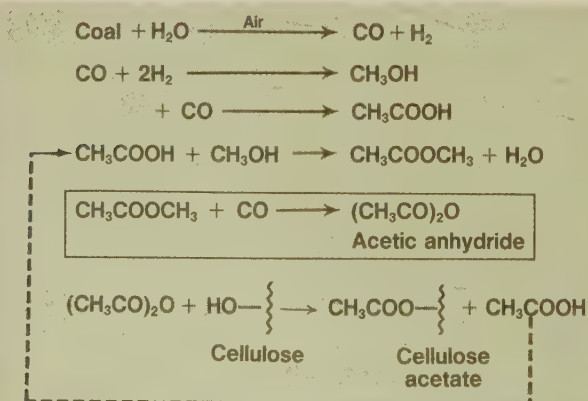


Figure 3. C₁ chemistry. Acetic anhydride production

of the late 1980s. Again technology comes to the fore, and there are at least four possibilities for alleviating the isobutene shortage. Isomerization of *n*-butane to isobutane is a familiar reaction in most refineries because isobutane is used for reaction with olefins to provide alkylate for gasoline. The isobutane may then be dehydrogenated to isobutene. The second process involves the isomerization of the butenes, which occur in the C₄ fraction from steam cracking, to isobutene. The third process involves cracking methyl alcohol in the presence of highly specific zeolites to give a mixture of olefins and alkenes rich in isobutane-isobutene. This reaction shows the power of zeolite catalysts, for earlier we described a potential process for propylene production via the cracking of methyl alcohol with a different zeolite.

Another approach is found in BP's Etherol process, which makes use of branched unsaturated compounds that occur in the gasoline, or so-called naphtha fraction, from fluid catalytic cracking (FCC). These are branched olefins that can give analogues of MTBE (Figure 2). Because most of the branched olefins in the FCC stream have terminal double bonds, a shift is necessary to provide a compound sufficiently active to react with methyl alcohol. The catalyst that makes this possible is a palladium-impregnated cationic-exchange resin, and from the standpoint of technology, the catalyst is trifunctional. In addition to promoting the double bond shift, it also causes doubly unsaturated compounds to be hydrogenated to monoolefins and catalyzes the reaction to produce ethers that are useful for increasing the octane number of gasoline.

Potential exhaustion of petroleum

In the 1970s and early 1980s we heard a great deal about the possibility that the chemical industry would not be able to get the petroleum feedstocks on which it is based. If petroleum is not available, the industry would logically switch to coal. Eastman showed that this could be accomplished through its creative process for preparing acetic anhydride from coal (Figure 3). Particularly noteworthy is the reaction in which the carbon monoxide is inserted into methyl acetate to provide the anhydride. This process has another interesting twist. The acetic anhydride is used by Eastman to acetylate cellulose to its acetate. In the process a mole of acetic acid is released and recycled, thus obviating the need to make acetic acid as shown in the third equation. The process is economical, as shown in Table 6, which compares the Eastman process with the standard process involving the pyrolysis of acetic acid.

A number of things can be learned from Eastman's development. First and foremost is that coal is a reasonable substitute for oil, and second that coal can be converted to the type of synthesis gas useful for chemical manufacture. A third point is that raw material costs using coal, as Table

Table 6. Economics of acetic anhydride production^a

	Ketene process	Carbonylation process
Capital investments, millions of dollars		
Plant	55.8	143.0
Utilities	21.2	73.2
	77.0	216.2
Working capital	21.2	14.9
Production cost, cents per pound		
Raw materials ^b	10.8	4.0
Utilities	3.3	2.1
Labor costs	4.4	3.9
overhead		
Cash cost of production	18.5	10.0
Depreciation	2.5	7.2
Net cost of production	21.0	17.2

^a Basis: U.S. Gulf Coast, 3rd quarter, 1982, 50 million pounds per year.

^b Acetic acid, 20.7 cents/lb.; coal, 1.9 cents/lb.; methyl alcohol, 8.2 cents/lb.; CO, 2.6 cents/lb.

Methanol synthesis from methane

Proposed



Conventional



Methane conversion

Proposed

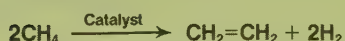


Figure 4. Conversion of methane directly to methyl alcohol

6 shows, are low. However, a fourth point is that this low raw material cost is a trade-off for high capital investment. Also, Eastman is located in a coal-mining area, thus obviating the cost of coal transportation. The answer to the question of whether coal can be used for chemical manufacture is not unequivocal. It obviously can, and Eastman's technology has gone a long way to prove this. However, extremely high capital investment would be required, and in all likelihood, a move of the chemical industry to the coal field.

A possible alternative to coal is methane, the major component of natural gas. Methane also can be made from coal, and if this were done at the coal fields the gas could be transported. However, methane is an unyielding molecule that does not easily give way to the chemist's bag of tricks.

The answer lies in the development of sophisticated catalysts, and chemists all around the world are hard at work trying to make methane a suitable raw material for the chemical industry. The first breakthrough probably will come in the conversion of methane directly to methyl alcohol (Figure 4). If this were possible, it would not be necessary to convert methane to synthesis gas as is done today; the synthesis gas would be reformed into methyl alcohol. This would mean that the large expense of synthesis gas production could be eliminated. Methyl alcohol could be available cheaply and could form a building block, by way of C₁ chemistry, for many of the needs of the chemical industry. The second breakthrough that the chemical world is seeking involves the conversion of methane to ethane or ethylene. Ethylene is the chemical industry's most important raw material; 40% of all the chemicals produced are based on it. Ethane can be converted to ethylene, either by dehydrogenation or by cracking. The chemistry of Figure 4 is the chemistry of the future that the industry is eagerly anticipating.

This paper is adapted from one delivered by the author at the ECMRA Conference, Rome, 1988.

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Pitfalls in reactor design

William B. Hooper

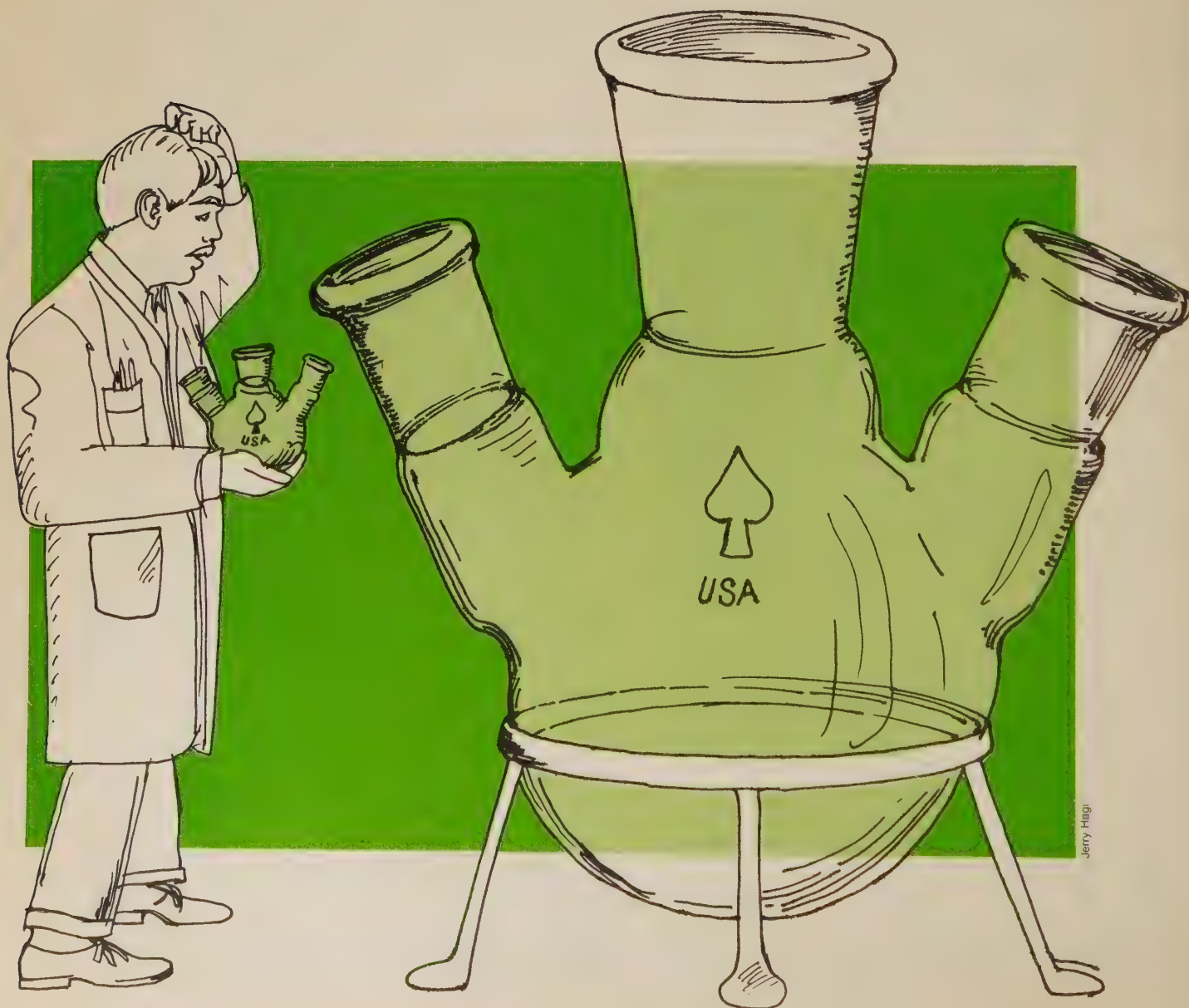
One of the glories of chemical technology is its ability to extract the underlying principles of behavior from complex natural systems. With the resulting correlations, we can predict effects of changes in operating conditions, and extrapolate from the laboratory or pilot plant up to commercial-size equipment. Our methods are so powerful that we tend to forget that they are approximations. From this neglect comes many a red face!

This discussion is based on my experience in starting up commercial reactors and in scaling up reactor designs from bench-scale research data. I assume that our primary

design tool is a computer simulation based on a kinetic model. The examples will emphasize problems caused by unexpected flow patterns and by mixing limitations. I'll cover only a few of the many creative disasters caused by reaction design engineers over the years.

Mixing

We can distinguish three classes of mixing. Mixing on the "macro scale" refers to blending of the feeds so that every gallon in a reactor has the same average composition as every other gallon. Mixing on the macro scale is



Jerry Hugi

controlled through the use of agitators, eductors, and spargers. Mixing on the micro scale refers to interdispersing the feeds to give uniform compositions down to the 10–100- μm scale. Mixing on the micro scale is controlled by eddies and is not affected much by agitation. Finally, mixing on the molecular scale is complete when every molecule in the reactor is surrounded by exactly the same neighbors at least on a time-averaged basis. Molecular-scale mixing is almost totally driven by diffusion. A completely stirred tank reactor (CSTR) implies good mixing at all three levels.

Does a well-mixed plant reactor really exist? The answer, of course, is no. Many agitated vessels are quite well mixed on the macro scale. Indeed, thousands of commercial reactors exist that are simulated satisfactorily using the CSTR assumption. Still, no commercial reactor can truly be perfectly well mixed. If one or more reactions are going on, there must be some concentration gradients on the micro scale. Often, the lack of perfect mixing can be ignored. If reaction kinetics are such that only the desired product can be made, then how and when the reactants get together may not be very important. Likewise, if the reaction rates are slow, the mixing may be adequate. In the real world, however, the reaction and mixing times are often similar and must be carefully studied. Consider a couple of plant examples where the CSTR simulation did not work well.

Some time ago we needed a simulation for a commercial massive fluid bed reactor about 3 m in diameter (Figure 1). The catalytic oxidation reaction using air is highly exothermic. Because the measured temperature variation throughout the bed is only a few degrees Kelvin, the bed is clearly well mixed. Based on this, a simulation assuming CSTR conditions was developed. It was a failure! When adjusted to fit one set of conditions, it then failed to predict operations under other conditions.

The results of a tracer study were surprising (1). A massive fluid bed reactor is about the best plug flow reactor known on the gas side. The solids are well mixed by internal recirculation, and this wipes out temperature variations. The gas moves up the bed as bubbles in plug flow. In fact, the residence time distribution (RTD) is narrower than it is in a laminar flow pipeline reactor. This characteristic can be used to keep feeds separated by bringing the feeds in through separate spargers at different elevations. Back-mixing in the gas phase is usually negligible.

Loop reactor

One of our plants has a loop reactor with fluid pumped from the reactor through a heat exchanger and back into the reactor (Figure 2). The loop piping is more than 30 cm in diameter. The controlling reactant enters the loop through a sparger between the pump and the heat exchanger. The reaction temperature is controlled at about

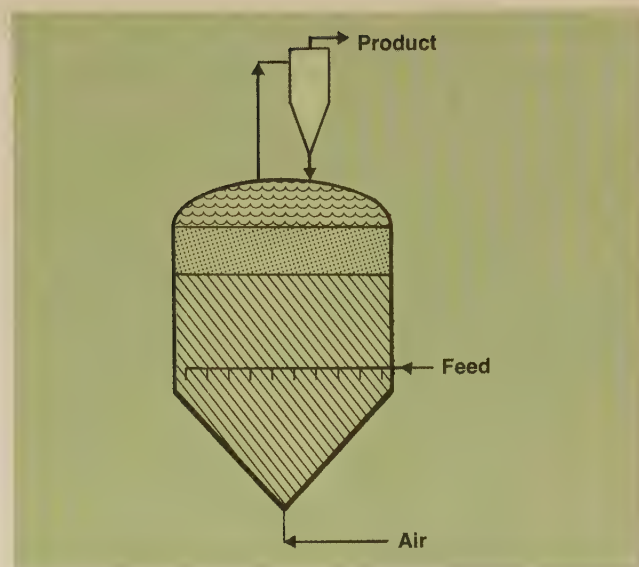


Figure 1. Fluid bed reactor

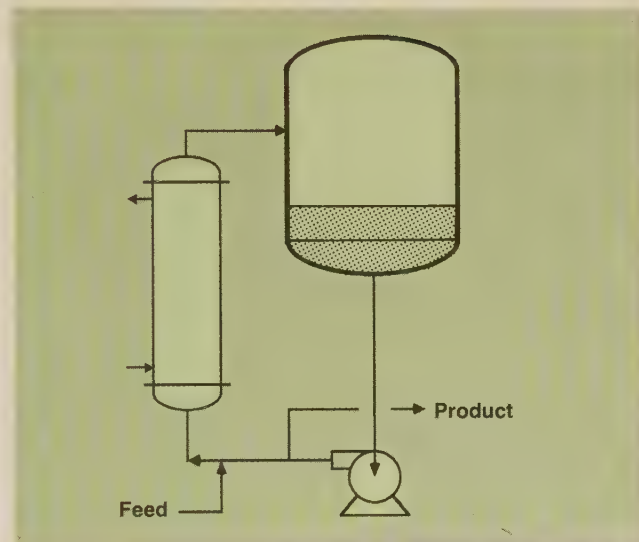


Figure 2. Loop reactor

50 °C. The reaction is highly exothermic and fast, like an acid–base reaction. The reactor was first modeled as a CSTR, but the resulting simulation did not match reality. A little reflection brought out that the reaction time was most likely shorter than the loop turnover time. This led to a model treating the loop as a plug flow reactor. Of course, the contents were assumed to be well mixed at any point around the loop—some improvement, but still a poor model.

Plant tests finally brought out that the limiting reactant was not dispersing uniformly across the recirculation pipe even though all fluids were fully miscible, the flow in the pipeline was fully turbulent, and the reactant was introduced at a high velocity through $\frac{1}{8}$ -in. holes. The reactant was still remaining in discrete droplets until it hit the high shear region at the heat exchanger tube inlet. This did provide the incidental benefit of delaying the reaction until the heat could be more easily removed. However, the



Figure 3. Cutaway views of the plug flow reactor



Figure 4. Cutaway views of the revised plug flow reactor

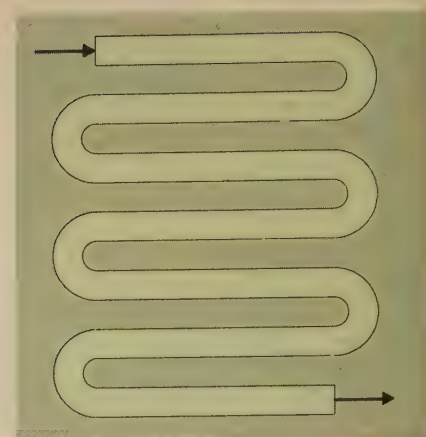


Figure 5. Pipeline reactor

lack of a uniform feed to the exchanger led to some tubes having too much heat duty and some too little. These insights into operating modes let us make some improvements in the reactor operation. The actual behavior turned out to be so complex that we had to abandon any attempt to simulate the reactor.

You call this plug flow?

Frequently, a process is developed using a bench-scale batch reactor. Economic considerations usually favor a continuous reactor in the plant. A "plug flow" reactor can give the same results as a batch reactor with the same residence time. To get high conversion, a plug flow reactor is frequently chosen for the plant design. Unfortunately, assuming a reactor to be a plug flow reactor doesn't make it act like one! Consider the following "plug flow" examples.

Baffled tank. A second-order reaction was carried out in a plug flow reactor. The reaction was fairly slow—the half life was 20 min or so. High conversion was an important goal. The design that was selected was a 3-m-diameter horizontal tank some 15 m long (Figure 3). A number of vertical segmental baffles were used to further increase the effective flow path. The required reaction time was about 90 min, compared with an average residence time provided of 120 min.

Startup was an experience best forgotten. Performance indicated a short residence time and poor conversion. A radio-tracer study showed that the initial breakthrough occurred in about 10 min. The peak on the RTD curve occurred at about 30 min, a fourth of what was expected. There was a long tail with tracer still coming out 12 h later. The main flow was clearly zigzagging down the center of the reactor. Much of the baffled area was almost dead. In fact, thermal stratification caused some of the material to just lie in the bottom for days. We modified the reactor to double the number of baffles and to change them from vertical to horizontal (Figure 4). This eliminated the thermal stratification and moved the RTD peak out to around 40 min. Even with these changes, the reactor never did come up to the design yield or conversion.

Pipeline reactor. How should a plug flow reactor be designed? A pipeline reactor is a common answer. One reactor design we tried used some 30 m of pipe 0.5 m in diameter (Figure 5). Some gas evolved during the reaction, so the pipe was essentially level and had very low

velocities. The design was a failure. The effective residence time was less than a third of the average residence time. Danckwerts in his classic paper (2) showed that in laminar flow the velocity profile is a parabola with a peak velocity twice the average. Thus we expected the breakthrough time to be at least half the average residence time. Apparently the pressure gradient was so small that the thermal density gradients caused large areas of the reactor to be stagnant. A later design with flow in the turbulent regime worked much better with the breakthrough time about 80% of the average residence time.

Predicting the true RTD

Frequently it will be obvious that a reactor cannot be treated as a simple CSTR or a simple plug flow reactor. Texts such as Perry's *Chemical Engineering Handbook* (3) show how a real reactor can be described by its RTD. Indeed, for first order reactions, a simulation made up of plug flow and CSTR units that matches the RTD can accurately predict the reactor performance. How can a process designer find the real residence time distribution? The starting point toward a good RTD is the recognition that it is determined by the flow patterns in the vessel. Entrance and exit effects often have an overpowering impact on reactor performance. A good way to predict flow patterns in commercial vessels is to test a small-scale hydraulic model. Lakin describes the use of a one-tenth scale plastic model of an existing reactor in a recent article (4). The model allowed his group to define the flow patterns in a complex geometry and then to optimize the mixing system. Our use of such a model to find out what was wrong in a large tank led to a simple way to improve performance (5). The total cost for our testing program was under \$1000.

Kinetics?

Having dealt with some problems in translating a computer model to the real world, let's consider some pitfalls on the path to the model. Most bench chemists prefer to work with batch reactions. By variations in the recipe and the residence time, it is often possible to work out the primary reaction mechanism. However, batch reactors give only the integrated results of the reactions. Fast reactions are often missed completely. This leads to an

incomplete reaction scheme that cannot be properly scaled up. It is better to use a small continuous differential reactor for investigation. Then you can explore all of the various composition regions.

Of course, the feed to a test reactor should be as close to the actual plant material as possible. More than once we have found that trace and unanticipated impurities are catalyst poisons or some other type of reaction modifier. In one classic case, corrosion products in the plant material turned out to be the catalyst that controlled the reaction rate!

Be sure to investigate a wide range of temperatures. Plant-scale reactors often have unexpectedly large local temperature swings. All micro volumes in which reactions occur are truly adiabatic. Temperature is controlled by heat transfer that is scale and geometry specific. Therefore, the true reaction temperatures are often many degrees away from what a thermocouple can measure.

Even after the correct reaction scheme and the correct kinetic constants have been determined, it is still possible to be misled by overlooking the impact of different mixing regimes. It is possible for one level of mixing to control reaction rates in a bench unit and another level in the plant. Consider the commercial reaction



where A, B, and D are reactants, P is the desired product, and Q and X are undesired byproducts. In one of our plants we found a major discrepancy in yields between the laboratory and the plant reactors. Only after much agony did we realize that the scale of mixing regimes was the source of the difference. Reaction 1 was fast; reaction 2 was the slow rate-determining step; reaction 3 was

intermediate in speed. In the laboratory reactor, A reacted with B before it could form X. In the plant, it took a few seconds for macro and micro mixing to get A and B together. During this mixing time, enough A was lost to X to seriously reduce the yield. A 1-mm-diameter stream disperses much faster than a 50-mm one!

In summary, computer simulations for designing or trouble-shooting a commercial reactor are usually built up using CSTR and plug flow elements. But no commercial reactor is ever fully a CSTR or a plug flow reactor. This may be unimportant if the desired reaction is dominant or all reactions are slow. A small hydraulic-scale model can be used to predict the residence time distribution of a plant reactor. This will guide in the selection of the proper type of simulation. Remember, vessel flow patterns, feed introduction methods, and mixing at all levels can create major operational problems if not properly addressed in the design stage.

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WHERE IT'S AT

[At the First Annual Symposium on Frontiers in Science, sponsored by the National Academy of Sciences] four of the six talks dealt with chemists tackling biological problems or harnessing biology for chemically well-defined tasks. This theme—long-standing problems in biology being addressed as essentially chemistry questions—is becoming a major trend in chemical research.

Rudy M. Bauer,
C&EN, March 20, 1989, p. 18

CRITICAL DIFFERENCES...

Americans want to keep up with the Joneses, even if it means a frenetic rat race. Russians worry about keeping the Joneses at their level; why should they get ahead? Concern about unjustifiable inequality and excessive privilege is a major source of resistance to Mikhail Gorbachev's reforms from the general population.

Flora Lewis,
The New York Times,
April 16, 1989

Calcium channels

How a simple ion
mediates myriad
life processes

David J. Triggle

Calcium serves two vital biological roles. It regulates membrane electrical potential, and as a cellular messenger it controls several important processes (Figure 1). Drugs that alter Ca^{2+} mobility have assumed importance as first-line cardiovascular agents and simultaneously served as molecular tools for dissecting what we call channel structures and function. Indeed, it may be argued that our molecular and therapeutic understanding of Ca^{2+} channel functions has depended almost entirely on the availability of these drugs (1).

Ions and molecules flow between the cell interior and its environment via specific transport systems. Structures in the cell walls that permit such transport are called channels. Traffic through ion channels creates a constant "noise," random opening and closing of the channels. However, cell membranes can be stimulated (excited) by specific chemical or physical effects to link, via channels, cellular excitation and biological response.

Cells must receive and respond to a variety of signals. Sensitivity is achieved through receptors tuned to chemical and physical inputs. These receptors are coupled to effectors (i.e., tissue components that carry out a response to the specific impulse). These effectors translate and amplify the information content of the incoming signal. Channels, a major family of effectors, control ion movements, an important mechanism through which the cell regulates excitability.

The cell maintains an asymmetric ion distribution across its membranes. This asymmetry is maintained through the selectively permeable properties of the cell membranes, through continuous energy input, and ultimately through metabolically driven ion transporters that serve to maintain ion gradients in the face of constant leakage and

to restore ion gradients after stimulation.

A generally similar distribution of ions across the cell membrane is maintained by most cells with a resting membrane potential of some -50 to -80mV . By convention, a negative potential is assigned to the cell interior. Typically, cells maintain a high intracellular concentration of K^+ and low intracellular Cl^- and Na^+ concentrations. The free intracellular Ca^{2+} concentration is very low. These ions are subject to both concentration and electrical forces tending to dissipate the gradients. Each ion thus may be characterized by an equilibrium potential where the concentration and electrical gradients are in equilibrium and where there is no net ion movement. Activation of a given ion channel permits the ions to cross the membrane so that the measured cell potential will shift to the equilibrium potential for that ionic species. Accordingly, the opening of Na^+ and Ca^{2+} channels allows these ions to flow into the cell interior so that the membrane becomes depolarized. This depolarization is normally an excitatory event, for increased intracellular concentrations of these ions initiate other events within the cell. For example, increased intracellular Na^+ leads to conduction in nerve fibers, and increased Ca^{2+} causes muscles to contract. Conversely, the opening of K^+ and Cl^- channels and the resultant hyperpolarization of the membrane is an inhibitory process.

The most important functional properties of ion channels are permeation and gating (the probability of channel opening). Figure 2 outlines the minimal organizational requirements for ion channel activity. These include a pore through which ions can permeate, an associated "selectivity filter" that gives the channel its



discriminating properties, and “gates” that open and close to permit ion permeation. The rates of opening and closing determine the activation and inactivation kinetics of the channels and the duration of channel open time. These properties can vary substantially between different

channel types. Additionally, channels possess sensors that permit them to respond in different ways to various chemical and physical stimuli, including hormones, pheromones, odorants, light, pressure, temperature, and electric potential.

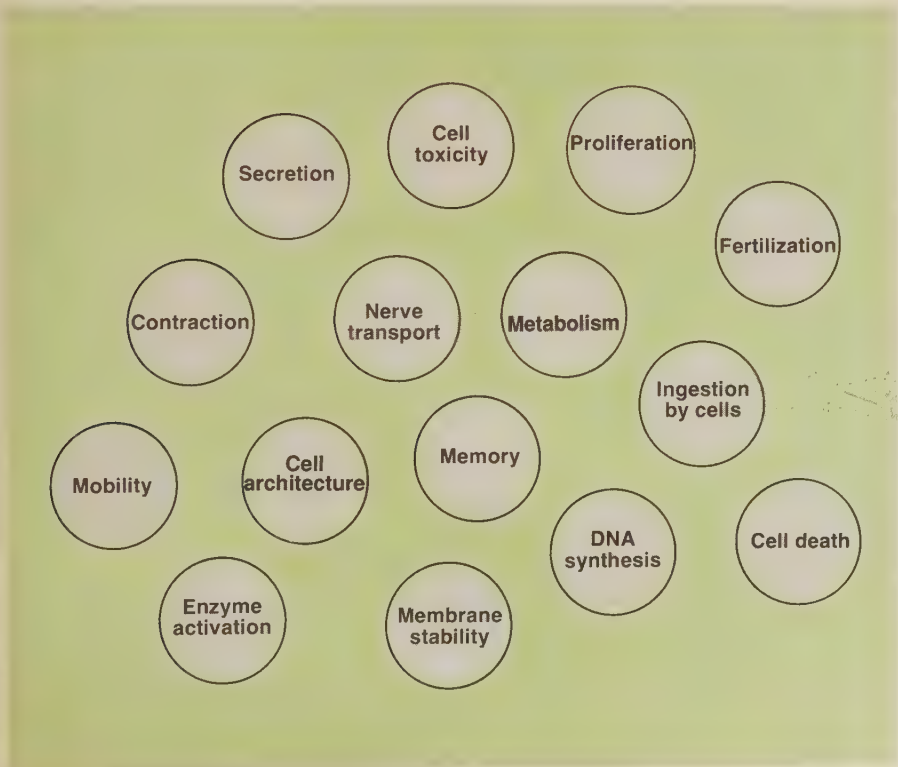


Figure 1. Calcium-mediated processes are vital to the health and welfare of the cell

Figure 2. Organization of an ion channel depicting the essential components

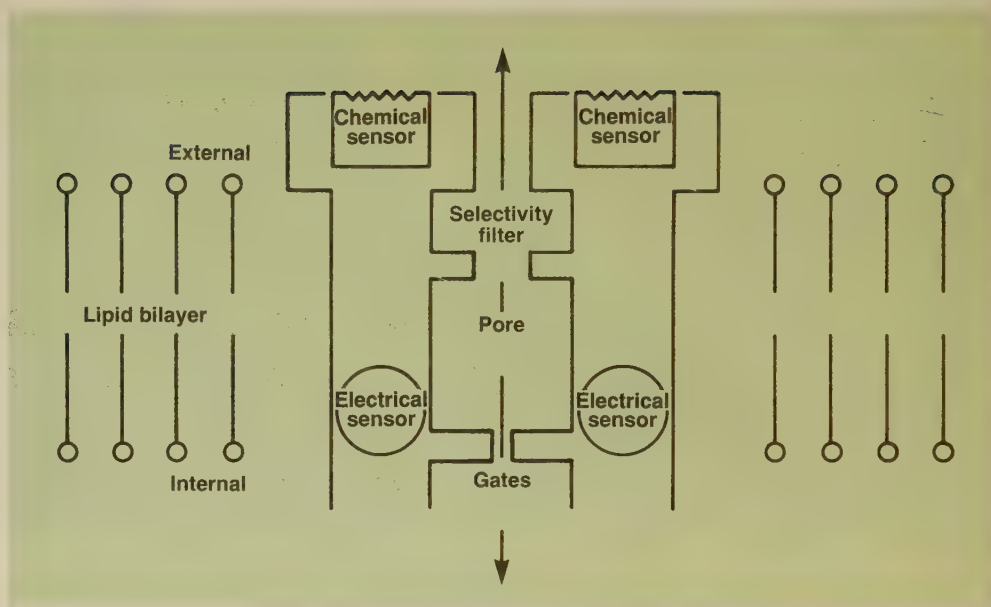


Figure 3. Postulated transmembrane organization of ligand-gated (upper) and voltage-gated (lower) ion channels. Both channel families consist of a discrete number of transmembrane helices. Ligand-gated channels appear to consist of several subunits that assemble to form the functional channel. Voltage-gated channels may consist of a single large protein made up of a series of repeats. One of the transmembrane helices in each region, S4, likely constitutes the voltage-sensing region.

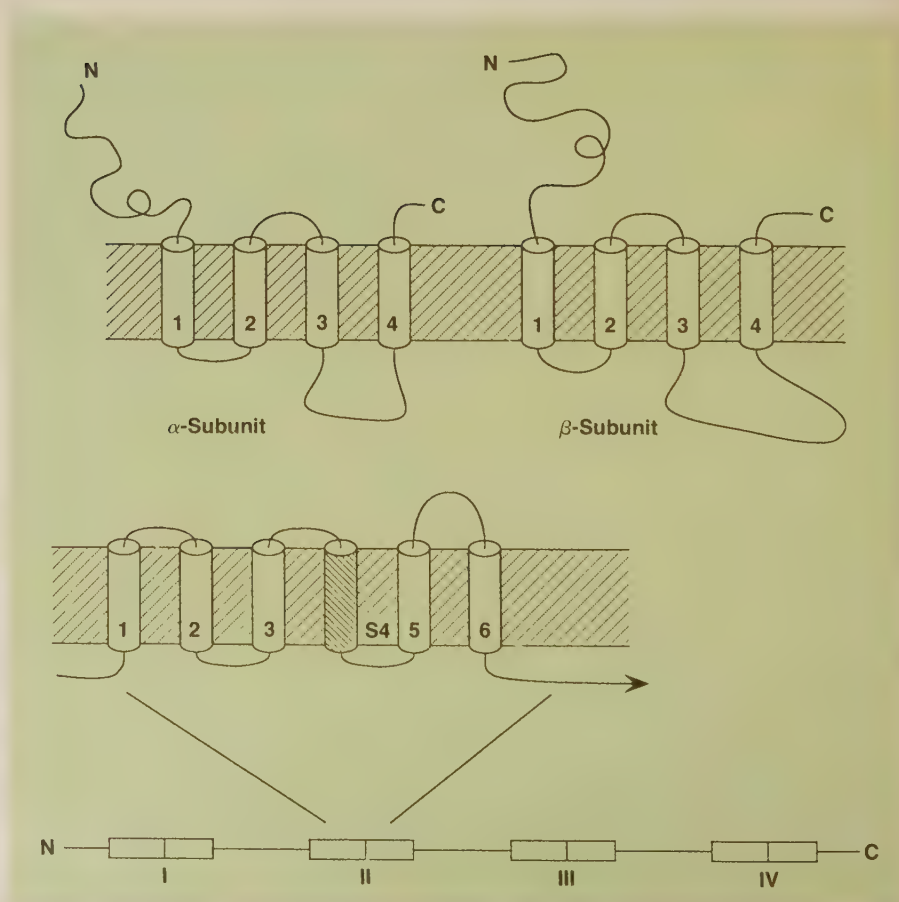


Table 1. Properties of Ca^{2+} channels

Property	Channel class		
	L	T	N
Activation range, mV	-10 mV	-70 mV	-30 mV
Inactivation range, mV	-60 to -10 mV	-100 to -60 mV	-120 to -30 mV
Inactivation rate	Slow	Rapid	Moderate
Conductance	25 pS	8 pS	13 pS
Permeation	$\text{Ba}^{2+} > \text{Ca}^{2+}$	$\text{Ba}^{2+} = \text{Ca}^{2+}$	$\text{Ba}^{2+} > \text{Ca}^{2+}$
1,4-Dihydropyridine (DHP) sensitivity	Sensitive	Insensitive	Sensitive
ω -Conotoxin sensitivity	Insensitive	Insensitive	Sensitive

Of particular interest are two major categories of channels:

- potential-dependent or voltage-gated channels, which are regulated primarily by electrical signals, and
- receptor-operated or ligand-gated channels, which respond to chemical signals.

The sensors are correspondingly activated by electrical or chemical potential changes.

The organization shown in Figure 2 does scant justice to the subtleties of construction and function of ion channels. In particular, ion channels are extremely efficient molecular devices that can permeate ions at rates $>10^7$ ions/s, close to diffusion-controlled limits, and yet maintain considerable ion selectivity based on the charge and size of the permeant species. Ion channels operate with efficiencies that are several orders of magnitude greater than enzymes or ion carriers. This efficiency of operation indicates that ion channels may function rapidly and at low membrane densities. Hence, ion channels are not major components of the cell membrane.

I assume that ion channels, of necessity, arose very early in cellular development. The lipid bilayer of the cell membrane represents a major barrier to the diffusion of charged species: Ion movements out of control are lethal signals to the cell. It is likely, therefore, that the development of ion-selective permeation mechanisms arose together with the development of control and regulatory devices, and that the efficiency of operation of ion channels represents the outcome of a long evolutionary path to perfection.

Structural studies are providing considerable molecular information concerning the organization and function of ion channels. Ion channels, which may be formed from single proteins or from oligomeric assemblies of proteins, contain membrane-spanning helical components. These components make up the ion permeant pathways. Additionally, ion channels likely exist as a limited number of structural categories whose individual members show substantial structural homology one to the other (2, 3). The voltage-gated and ligand-gated ion channels constitute major structural families and include the Na^+ , K^+ , and

Ca^{2+} channels and the γ -aminobutyric acid, glycine, and nicotinic acetylcholine receptor-channel complexes, respectively (Figure 3). It is likely that these channel classes originated from a common ancestral ion-transporting protein to which has been added the ion selectivity and regulatory properties now apparent in the individual channels.

Ion channels are major foci of cellular control processes and targets of physiologically significant regulatory inputs. Ion channels also provide major targets for drug and toxin actions. Important groups of drugs that act at ion channels include the local anesthetics active at Na^+ channels and the blood sugar-lowering sulfonylureas active at K^+ channels. Additionally, ion channels have proved to be major targets for the toxins of venomous animals, including spiders, mollusks, and snakes. These toxins are often a mixture of agents active at several distinct categories of ion channels, presumably reflecting a more efficient protective or killing mechanism. Thus the toxins from the fish-eating mollusks of the *Conus* genus interact at Na^+ channels, Ca^{2+} channels, and the nicotinic acetylcholine receptor-channel complex; their combined action doubtless compensates for the apparent mismatch of freely swimming fish and sluggishly mobile mollusks (4).

The Ca^{2+} channel

At least three major categories of Ca^{2+} channel exist. Termed L, T, and N, these categories may be distinguished by electrophysiologic, pharmacologic, and distribution criteria (6). These criteria are summarized in Table 1. The low threshold of activation of the T channels suggests that they may be well suited for pacemaking function, whereas the higher conductance of L channels and their higher threshold of activation indicates a role in responses, including excitation-contraction coupling, where large and sustained changes of cellular Ca^{2+} concentration occur. Finally, N channels appear to be confined to nerve cells (neurons), where they regulate neurotransmitter release. It is unlikely, however, that the cellular roles of these channel types are totally separate; it is probable that some cellular responses, particularly in neurons, require

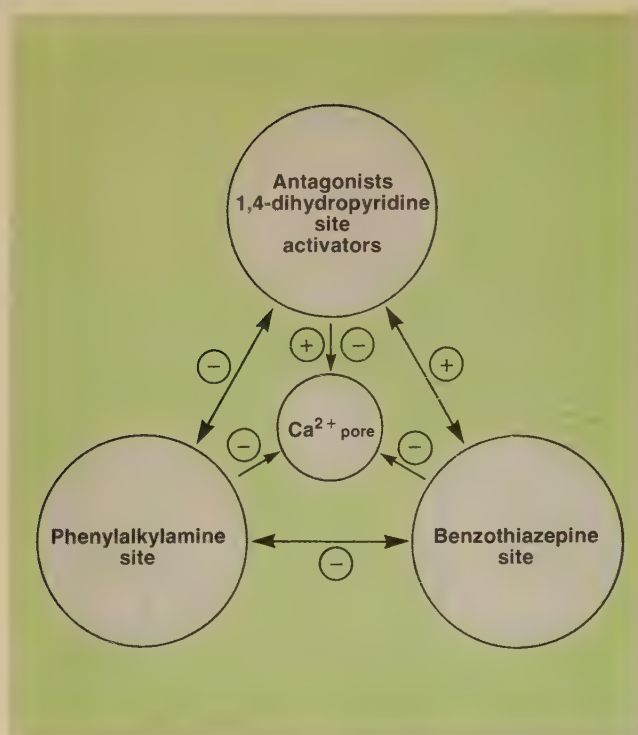


Figure 4. Mode of interaction of calcium channel drugs. —, inhibitory; +, stimulatory

the combined activation of at least two channel types. Additionally, each of these major channel classes is likely composed of subclasses with distinguishable pharmacology and localization.

Drugs effective at Ca^{2+} channels

From the perspective of drug development, the most important distinctions between these channel classes are based on the actions of selective drugs. A group of synthetic agents, the Ca^{2+} channel antagonists, including the clinically available 1,4-dihydropyridine nifedipine, the phenylalkylamine verapamil, and the benzothiazepine diltiazem (Figure 4), are selective for the L class of channel. This selectivity of action and the dominant role of the L class of channel in the cardiovascular system underlie the major therapeutic roles and effectiveness of these drugs against the several forms of angina, some heart arrhythmias, high blood pressure, and other vascular disorders (Table 2) (7). Sales of these agents in North America are projected to approach \$3 billion by 1992 (8).

The major Ca^{2+} channel antagonist drugs of Figure 4 interact, consistent with their chemical heterogeneity, at three distinct but allosterically linked sites on a major polypeptide component of the channel. Each of the sites depicted binds a separate structural class of drug and exhibits a discrete structure-activity relationship. The 1,4-dihydropyridine site is of particular interest because it can accommodate both potent antagonist and activator species. The existence of such activator species raises an important question about the existence of endogenous ligands that physiologically regulate the channel and whose functions are mimicked by the synthetic agents of Figures 4 and 5 (9).

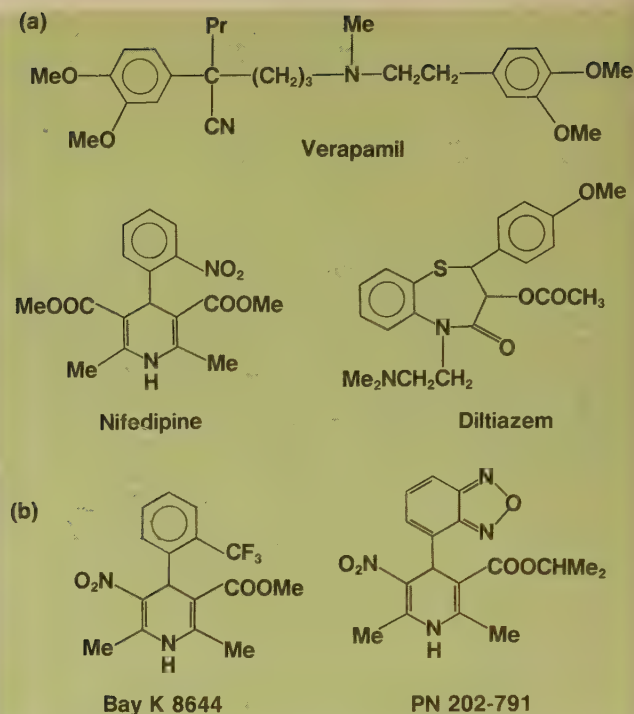


Figure 5. Calcium channel drugs. (a) antagonists, (b) activators

The affinity or access of drug to its receptor site depends on the channel state—resting, open, or inactivated. According to this “modulated-receptor hypothesis,” antagonist drugs interact preferentially with the inactivated channel state, which they can access, according to drug structure, via hydrophilic or hydrophobic pathways. Activator drugs interact with and stabilize an open channel state. These state-dependent interactions are significant contributors to the observed tissue selectivities of the existing Ca^{2+} channel antagonists.

Future developments in Ca^{2+} channel drugs will likely pursue several paths. There is no reason to assume that only three major drug-binding sites are found on the L class of voltage-dependent channel. By analogy to the Na^+ channel, with which the Ca^{2+} channel shows substantial homology (2), five or more classes of binding sites may exist. Subtypes of the major L class of channel likely will be found to exhibit discrete tissue distribution. This advances the possibility for additional and more selective groups of agents. The current Ca^{2+} channel drugs are effective in the peripheral systems. There will clearly be continued search to exploit the Ca^{2+} channel pharmacology in the central nervous system, which has many drug-binding sites. Recent work showing that nimodipine, a 1,4-dihydropyridine analogue of nifedipine, can facilitate memory processes and reverse motor deficits in aged animals is indicative of the interest in this area (10).

No synthetic agents are now available for the T and N channel classes of comparable potency and specificity to those available for the L channel. However, the pharmacology of these channels, particularly the N channel, has been exploited in nature to lethal ends. The venom of certain mollusks and spiders contains toxins of

Table 2. Therapeutic uses of Ca²⁺ antagonists

Use	Antagonist		
	Verapamil	Nifedipine	Diltiazem
Angina:			
Exertional	+++ ^a	+++	+++
Anginal spasm (Prinzmetal's)	+++	+++	+++
Unstable	+++	+++	+++
Irregular heartbeat:			
Paroxysmal supraventricular tachyarrhythmias	+++	—	++
High blood pressure	++	++	+
Heart muscle overgrowth (Hypertrophic cardiomyopathy)	+	—	—
Peripheral constriction of arteries (Raynaud's phenomenon)	++	++	++
Open heart surgery ^b	+	+	+
Blood vessel spasm following strokes	—	+	—

^a Plus and minus signs indicate extent of use: +++, very common; —, not used.

^b To reactivate heart muscle after it had been paralyzed to permit surgery.

considerable specificity and potency for the N class of channel (4, 11). The ω -conotoxins from fish-eating mollusks of the *Conus* genus interact with neuronal N channels. These peptide toxins, 25–29 residues, likely characterize two or more different subclasses of neuronal channel with species and tissue selectivity. The venom from funnel web spiders also contains toxins selective for neuronal Ca²⁺ channels, although the structures of these agents, of both low and high molecular weights, remain to be determined. These toxins or their synthetic peptide analogues are unlikely to find therapeutic application; nevertheless, they are valuable for their ability to determine the roles and properties of neuronal Ca²⁺ channels. In addition, their radiolabelled forms permit regional and cellular localization of these channels.

In principle, the ability to selectively modulate neurotransmitter release in discrete brain areas may have widespread applications and provide alternatives to the current therapies of such neuronal disorders as psychoses, depression, and mania. Through use of these toxin probes, synthetic agents with comparable selectivity may be developed for pharmacologic and possibly therapeutic exploitation of these neuronal channel types.

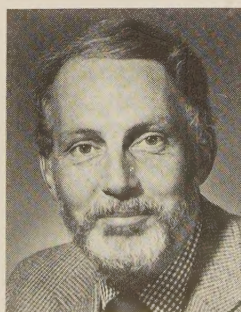
Summary

Ion channels represent foci of cell excitability control. It is important to understand the structure and function of these channels for several reasons. Elucidation of permeation mechanisms will help us understand how ion transport occurs with both efficiency and selectivity. Delineation of the control processes for ion channel function is important from the perspective of drug development. Ca²⁺ channels are of particular relevance because they control the availability of Ca²⁺ as a cellular messenger. Already synthetic agents are used as major

cardiovascular drugs. It is likely that continued exploitation of Ca²⁺ channel pharmacology will lead to new drugs and expand our therapeutic horizons for these agents. As is the case with other categories of ion channels, nature has already taken advantage of their critical role in cellular control via various toxins secreted by plants and animals. Such agents may well prove to be tools for the further development of Ca²⁺ channel drugs.

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Heart Cut

(continued from p. 28)

The technology of ceramics processing is described in several articles in the October 1988 issue of *Am. Ceram. Soc. Bull.* Among the topics discussed are turbomilling of ceramic powders, hydrothermal synthesis, **plasma processing**, and pressure casting. (KFS)

How well does it stick? Or, in tech talk, what's the nature of the adhesive/substrate interface? That's what determines the efficiency of the adhesion. Using infrared reflection-absorption spectroscopy, R. O. Carter III and colleagues (*Ind. Eng. Chem. Res.* 1989, 28, 48) examined the **interfacial reactions** of a dicyandiamide-crosslinked epoxy system on zinc and steel. Although no changes were found when the adhesive was heated on steel or zinc-oxide-coated steel, dicyandiamide is apparently reduced by reaction with the metallic zinc, indicating the formation of a unique product at the adhesion interface. (CMH)

Separation of toxicants from blood is an increasingly important role for semipermeable membranes. However, many polymer **membranes disrupt red cells**. K. Sakai and colleagues (*Ind. Eng. Chem. Res.* 1989, 28, 57) prepared microporous glass membranes that promise to overcome this problem. Made from $\text{Na}_2\text{O}-\text{B}_2\text{O}_3-\text{SiO}_2-\text{Al}_2\text{O}_3-\text{CaO}$, these membranes can be sterilized, are regenerable by rinsing or applying high heat, and have a narrow pore size distribution. (CMH)

The four R's—recovery, reuse, regeneration, and recycling—are the best answers to waste problems. In melamine production, waste solids create major pollution problems as well as considerable loss of raw material. S. M. Lahalih and M. Absi-Halabi (*Ind. Eng. Chem. Res.* 1989, 28[4], 500) **recovered waste solids** and, via a multistep process, produced sulfonated resins that are excellent dispersants. Added to concrete and soil, they increase compressive strength remarkably. Added to drilling mud, the resins improved rheological characteristics comparable to a commercial lignosulfonate additive. (CMH)

Accidental release? Now there's a "computer expert" to help you choose the right model for its scenario. BREEZE HAZ CONSULTANT (Trinity Consultants, 214-661-8100) requests information about what might be released, from where, and in what quantities and then **tells you which of the many existing models** is the appropriate one for your purposes. (MRD)

Sodium perborate is a selective, cheap, safe, and easily handled oxidant. A. McKillop and co-workers explored its versatility in two recent papers (*Tetrahedron* 1987, 43, 1753; and 1989, 45, 3299). Conversions include **ketones to esters**, **anilines to nitroarenes**, aromatic

aldehydes to acids, iodoarenes to diacetoxyiodoarenes, and the oxidative hydration of aromatic nitriles to amides. (AJC)

Chemistry at high temperature in aqueous solutions is discussed in several articles in the September 1988 issue of the *Journal of Solution Chemistry*. Modeling of aqueous **solutions near the critical point of water** is among the topics covered. (KFS)

Separation of the rhodium catalyst from hydroformylation reactions has been facilitated by using water-soluble phosphine ligands. This technique now has been utilized in making **supported liquid-phase** catalysts. J. P. Arhancet et al. describe the application to hydroformylation in a recent letter to *Nature* (1989, 339, 454). Because the reaction takes place at an interface, changes in selectivity are possible. The ratio of linear to branched products for the reaction of 1-octene was, however, in the normal range (1.8–2.9). Advantages were the absence of any leaching into the organic phase and an increased catalyst stability at low water loadings. Applications to other catalytic reactions are said to be under investigation. (AJC)

High blood cholesterol levels, with their implication of increased risk of coronary heart disease, remain a hot topic. Half of all Americans aged 30–69 are estimated to have borderline or elevated cholesterol levels (Wilson, P.W.F. et al. *JAMA* 1989, 262, 41), and many are in need of medical intervention (Sempos, C. et al. *JAMA* 1989, 262, 45). Since we mentioned the value of niacin and oat bran for treatment (CHEMTECH, November 1988, IBC) **sales of niacin tablets increased fivefold** (*Chem. Mark. Rep.* May 29, 1989, p. 15). An alternative to oat bran is a popular laxative, psyllium hydrophillic mucilloid (Bell, L. P. et al. *JAMA*, 1989, 261, 3419). An excellent review of current therapy is provided by C. B. Blum and colleagues (*JAMA*, 1989, 261, 3582). (AJC)

Palladium catalyzed carbonylations of organic halides are limited to those whose palladium derivatives do not undergo β -hydride elimination (aryl, alkenyl, benzyl, and allyl). Platinum phosphine complexes now have been found to catalyze the carbonylation of simple primary and secondary **alkyl iodides to esters** (Watanabe, Y. et al. *J. Org. Chem.* 1989, 54, 1831). A pressure of 70 kg/cm² is required, presumably to allow carbonylation to compete effectively with elimination. Aldehydes are obtained in the additional presence of hydrogen, which is the result of an initial loss of HI and subsequent hydroformylation. Alkenyl and alkynyl iodides are also carbomethoxylated. (AJC)

The steeping step in the semicontinuous process for making starch from corn varies from 36 h to 60 h, depending on the type of corn. That's substantially longer than all subsequent steps. Adding phytic acid-degrading enzymes (Econase EP 434) together with plant **cell wall-degrading enzymes** to the steep liquor

reduced steeping time considerably, according to A. Caransa and colleagues (*Starch* 1988, 40[11], 409). The use of enzymes also resulted in a higher yield of the starch and lower energy consumption. (PLS).

A. I. Popov, N. S. Kopolev, and Yu. M. Kiselev have prepared a **neat tabulation** of the radii of the 3+, 4+, and 5+ ions of the *d*-transition elements (*Doklady Akad. Nauk SSSR (Engl. trans.)* 1988, 301, 223). (HWY)

The automatic dishwasher has indeed come a long way. For a mere 5 grand you can get a dandy stainless-steel unit made in Germany by Miele (201-560-0899). Its individual trays and their associated plumbing enable you to **wash and dry the most exquisite glassware** (volumetric flasks are a cinch) and rinse twice with deionized water. Although the up-front cost is high, it doesn't take long to pay it out, if one is using hand washing. (BJL)

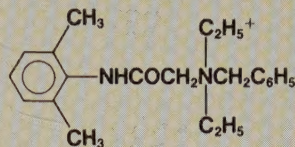
Here's a way to improve adsorption. Surfactant-modified sorbent (that old standby, $\text{Ca}[\text{OH}]_2$) allows increased adsorption of SO_2 from stack gases (Kirchgessner, D. A.; Jozewicz, W. *Ind. Eng. Chem. Res.* 1989, 28[4], 413). The surfactant, calcium lignosulfonate, appears to **allow use of smaller pores**, thus increasing the surface area available for SO_2 deposition. (CMH)

If you ever want technical information from Europe and your local library can't help, try the new 8th edition of *European Sources of Scientific and Technical Information* (Longman, 1989, Order no. 76123-482 from Gale Research, \$215/set, 1-800-223-GALE). The book, arranged by type of information handled, includes **1500 key sources**, libraries, research institutes, and museums, in all the countries of Europe, including such usually forgotten as Luxembourg, Albania, and Cyprus. (MRD)

To **get rid of all types of freon**, use Toyo Soda's process to heat them with air to about 500 °C and pass the stream through a zeolite. Decomposition products are CO_2 , HCl, and HF, which are neutralized with existing techniques (*Jpn. New Mater. Rep.* 1988, 4[4], 7). (DLN)

As so often happens when the press features erroneous or biased information, the correction or rationalization is hidden away and appears weeks later. Such was the case for two letters in *Chemical and Engineering News*, one treating the hazards of radon, the other of Alar. The **rebuttal pieces are worth reading**. The one on the former appeared March 13, 1989, p. 3, while that on the latter appeared June 19, p. 4. The latter was written by J. A. Lacadie, director of crop protection R&D for Uniroyal, which was forced to take Alar off the market because of public pressure aroused by, among others, that eminent toxicologist Meryl Streep of the Natural Resources Defense Council. (BJL)

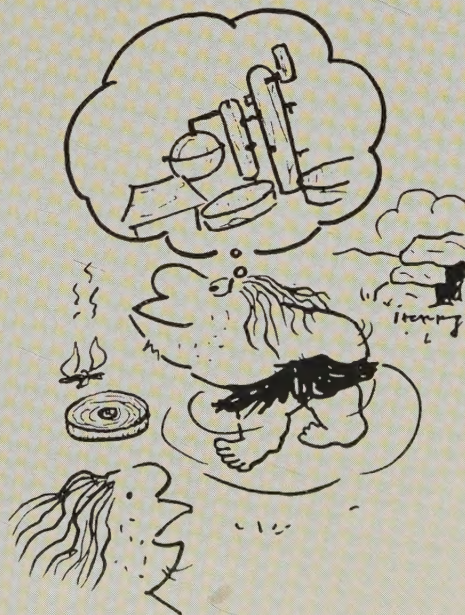
If you are interested in the ultimate in bad taste, look to U.S. Patent 4652577 from G. Hollander and M. Blum of Atomergic Chemetals for a new standard. Apparently, up to now **the world's worst-tasting compound** was something called denatonium benzoate, used as an additive to make various materials unpalatable. To inhibit rats and other animals from chewing through cables or eating plants, an even more unpleasant material was needed, and denatonium saccharide is the result.



It is appalling even at one part in 10^8 , according to the inventors (*New Sci.* 1989, 122[1662], 33). (RJP)

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"The wheel, fire! What foolish idea is it now?"

THE LAST WORD

John C. Marshall

Confessions of a computer addict

I am a computer addict. I own two microcomputers with more memory and more processing power than anyone needs, and yet I look longingly at newer, faster machines with better graphics. I have a vast collection of software packages, only some of which I know how to use. Hardly a week goes by that I don't have the opportunity to upgrade something that I own. One word processor that I have has been upgraded three times in the past year.

I have program upgrades on my shelf I have not had time to install. New software and hardware are appearing all the time that I simply must own if I am going to keep up.

Yesterday I received an announcement that some software package that I own had gone through yet another revision. The announcement warned me that I must have this most recent version because without the wealth of new features it contains my life would be incomplete. Naturally, I signed immediately on the bottom line of my checkbook.

I purchased my computers to help me work more efficiently. But now I spend so much time preparing my software and hardware that I can't find time to do my work. I spend countless hours reading computer magazines that people send me for free.

Those of us who have grown up during the microcomputer revolution have implicit faith that all of this will extrapolate to nirvana. But it will not. Developments in many areas are approaching limits asymptotically. Revolutionary changes, those that move capabilities ahead by an order of magnitude or more, are rare and very expensive. The computer market is becoming mature, and one of these days we are going to have to wake up and ask some serious questions about this reckless quest for the fastest, biggest, neatest, and latest. Will my life really change if my spreadsheet recalculates in 5s instead of 10s?

I remember that we were going to have the "electronic office." No paper, right? But we are drowning in paper, and it gets worse as computers continue to make producing it easier and faster. Speaking of paper, when I moved to a 24-pin dot matrix printer I thought I had reached the end of my

printer buying spree. Now I find it hard to look at the documents that my printers produce. Yes, I will buy a laser printer. I must!

I need help! I feel a PS2 Model 80 coming on. I must have one so I can be ready for the "486 and "586 and "n86 machines that are sure to follow. I fantasize about how confident and happy I will be when I am typing a memo (which I will output on my 600-dpi color laser printer) to know that I can call on some uncountable number of gigabytes of virtual memory (should the need ever arise) on a machine so fast that the Norton SI rating (1) must be displayed in exponential notation. Why is enough never enough in this business?

The time has come to found an organization called Computers Anonymous (CA). Members would first have to acknowledge publicly that they are helpless pawns of the computer industry—that they have an uncontrollable desire for bigger and faster hard disks, higher Norton SI ratings, and elaborate software solutions to problems they don't have or even understand. Members would promise to drop their subscriptions to *InfoWorld* and *Byte* and to never order software updates for software packages they don't use. Naturally, members would agree to avoid all

computer stores and destroy all those 800 numbers that they spend hours trying to reach in order to have the opportunity to spend their money. Members would agree to be on call day and night to provide help and strength in case one of the group is about to fall off the wagon, perhaps to squander the rent money on a new high-resolution color monitor or order a \$10,000 CAD/CAM system with which to play tick-tack-toe. There is also a need to address the suffering of neglected spouses and computer orphans with a companion organization.

One day I am going to kick this habit. Yet I do feel a strong need for Version MCXII.12 of my word processor, which includes the ability to do interlinear translations of the Greek and Hebrew versions of the Bible.

Reference

- (1) A rough measure of processor capability that uses the IBM-PC-XT as its standard of comparison.

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Tina Mion